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ANALYSIS OF SSME HPOTP ROTORDYNAMICS
SUBSYNCHRONOUS WHIRL

FINAL REPORT

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1.0 INTRODUCTION

The early development phase of the Space Shuttle Main Engine (SSME) was plagued by a number of problems in which components failed virtually without warning. Frequently, these components were in one of the two high pressure turbopumps which are a part of each engine. Turbopumps, like any rotating machinery with high speed, light weight rotors have historically been subject to vibration problems that occasionally lead to fires and even violent destruction of the hardware. Because of the extreme complexity of turbopump dynamic behavior, the process of gaining a thorough understanding of the causes has been difficult. Testing the elaborate hardware of the SSME has also been difficult and extremely expensive.

The analysis of the dynamics of the SSME and particularly of the high pressure turbopumps presents the analyst with a challenging problem. Nevertheless, to gain an understanding of the vibration and whirl problems of the SSME, one must develop and exercise analysis and simulation tools. The primary tools developed for this analysis consist of a nonlinear, hybrid computer simulation and a stability model based on a linearized version of the same equations of motion as used in the nonlinear model.

The purpose of this study effort is to continue work begun under an earlier study contract (NAS8-34924), assisting NASA/MSFC to analyze causes and fixes to vibration and subsynchronous whirl problems encountered in the SSME turbomachinery. Because the nonlinear and linearized models of the turbopumps play such an important role in the analysis process, the main emphasis of our work has been concentrated on the verification and improvement of these tools. It has been the goal of our work to validate the equations of motion used in the models including the assumptions upon which they were based and to assure that

the linear stability model and the hybrid model predict consistent behavior in the regimes where they should. Several tasks were identified at the outset of this study: 1. Verification of the SSME rotordynamics simulation and the development of enhancements. 2. Assistance in the review and identification of potential mechanisms of subsynchronous whirl and the development and verification of fixes. The primary whirl mechanisms were identified under the earlier effort and since an investigation of fixes must await a fully verified simulation, the primary effort of this study was devoted to the first task.

The thorough checkout of the simulation has been accomplished and a few minor discrepancies have been discovered. These will be explained in detail within this report with recommendations made for their correction and an assessment of their impact upon previous results. A filtering technique has been developed to enhance the speed in which results from the simulation can be analyzed for frequency content of the signals. Its development and results will also be reported here.

2.0 SIMULATION VERIFICATION

During this study our efforts were concentrated on verifying the SSME rotor dynamics hybrid simulation and confirming that the linear results agree with those of the linear stability model derived from the same set of equations. The outputs of the linear stability model are eigenvalues and eigenvectors. The eigenvalues reveal the stability properties and the vibration frequencies that will be present in the response of the linearized system. The eigenvalues should approximate the nonlinear responses as well. The eigenvectors represent the normalized amplitudes of motion at the frequency of the corresponding eigenvalue. Both eigenvalues and eigenvectors are functions of all the model parameters. The system response is a superposition of all the eigenvectors at amplitudes determined by initial conditions and the disturbances acting on the system.

Our verification method consists of making a detailed audit of the simulation code and comparison with the derived equations of motion and of matching frequencies and damping ratios between comparable cases run on the hybrid simulation and the linear stability model. Agreement between model results over wide variations of each of the system parameters gives us a very high confidence level (approximately 99%) that the two models agree both in implementation of the model equations and incorporation of an extensive data set.

Our primary verification technique is to make the hybrid simulation linear by eliminating some disturbances and setting all the nonlinearities (bearing deadbands, sideloads, squeeze film damping, unbalance forces and internal Coulomb friction) to zero. Then we observe the transient response. In this configuration, the stability and response characteristics of the hybrid should

duplicate the results from the stability model in frequency and decay or growth rate of the response amplitudes.

Since responses of the linearized hybrid simulation contain multiple frequencies, it is difficult to compare responses to predicted frequencies unless a single frequency is dominant. When the system is unstable the instability amplitude grows to dominate the other responses at the characteristic frequency. The amplitudes approach zero asymptotically in a stable case. The cross coupling terms of the whirl drivers are used to set up conditions which the stability model predicts to be unstable. The results are examined to assure that the hybrid simulation shows the instability at the proper frequency as determined by the whirl velocity, the proper direction of whirl, and the proper growth rate.

The force coefficients which define the force models used in the simulation and the stability models vary with the rotor speed (PHIDX). This variation is modeled by a polynomial curvefit relating the coefficient to a polynomial function of PHIDX. The seals are modeled as quadratic functions of rotor speed and in most cases only the term coming from PHIDX squared is nonzero. We studied the cross coupling coefficients and their effects on whirl stability and compared the hybrid and linear models.

The third cross coupling coefficients at the Alford force/turbine interstage (SQA2), hot gas (SQ12), and preburner pump (SQ22) seals; cross coupling at the impeller/diffuser interaction point (SQ32), the Alford cross coupling multiplicative factor (BETA), and the rotor internal viscous damping (TWOZETR) are the stability parameters. For convenience, in this report they will be referred to as SQA, SQ1, SQ2, SQ3, BETA, and ZER. Figure 1 shows the positions of the whirl drivers on the turbopump model.

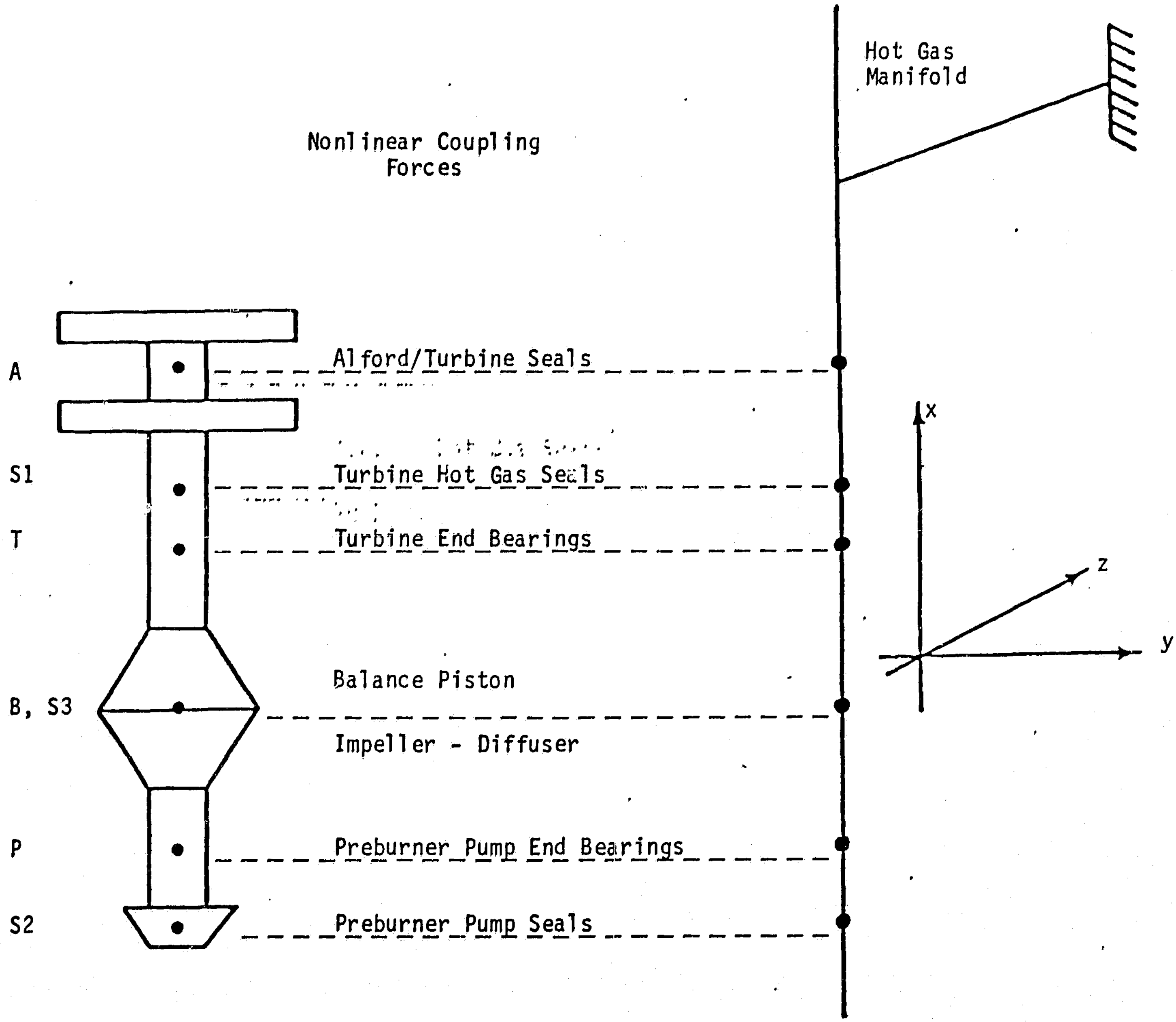


FIGURE 1 HPOTP Model

The methods we use to analyze the hybrid simulation results that are sent to the strip chart recorders are derived and illustrated in Section 2.1. Section 2.2 is a discussion of the error due to machine tolerance or operator limitations that one can expect in the final results. Investigation of discrepancies during the verification process revealed data input differences and simulation coding errors that are described in Sections 2.3 and 2.4. Section 2.4 also includes an error in the equations of motion that the simulation is based on. Our study of the simulation responses indicated other problems that are probably due to the hardware peculiarities but were not verified as such. These responses and implications are discussed in Section 2.5. Examples of hybrid simulation and stability model results are in Appendix B.

2.1 DATA ANALYSIS METHODS

Our analysis of hybrid simulation results concentrates mainly on two parameters: the primary response frequency (Omega) and the damping coefficient of the response amplitudes (Alpha). Omega is derived from simulation variables VWP and VWT (pump and turbine end whirl orbit angular velocities) which are output to strip chart recorder channels 23 and 24. Alpha is calculated from rotor displacements in either the Y or the Z direction. We chose displacements at the Alford Seal location (DEAY or DEAZ) because these channels (11 and 12) are the most reliable pair in terms of pen and recorder behavior. Before any calculations are made the direction of whirl is noted. Whirl mechanisms studied in this report are forward whirl producers; i.e. the rotor angular velocity (PHIDX) and whirl orbit angular velocity are parallel. Any deviation would indicate a backward whirl mechanism or a simulation error. The whirl in Figure 2a is forward, and that of the last part of Figure 2b is backward.

The magnitude of the whirl orbital velocity was originally approximated from the arithmetic mean of the maximum and minimum displacements of VWP or VWT. Some simple calculations indicate that the geometric mean produces more accurate results. This is demonstrated below:

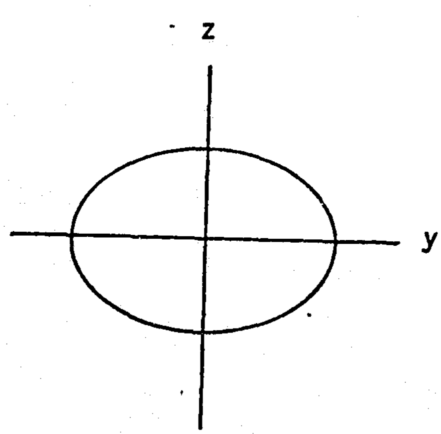
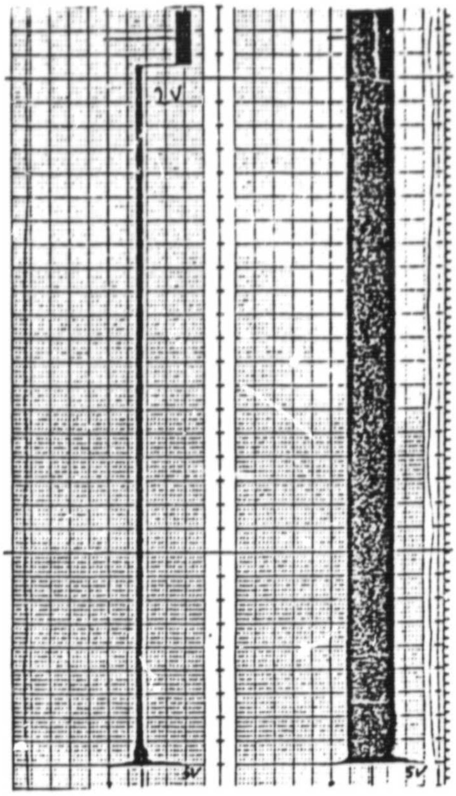


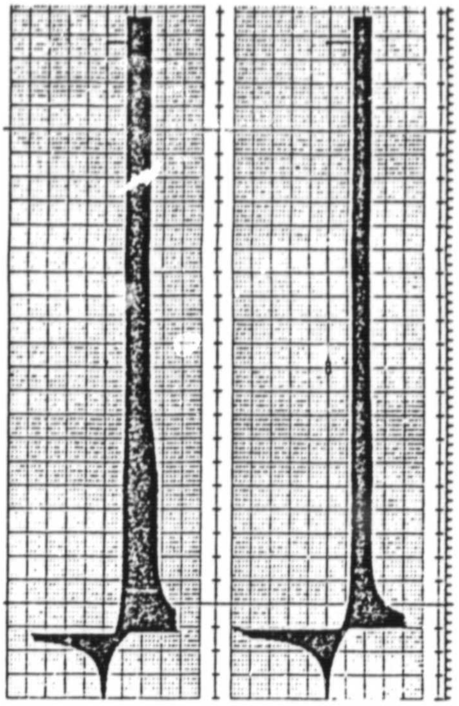
FIGURE 3



VWP = -3856   VWT = -4219

PHIDX = -3194.5
SQ3 = .0085

2a



VWP = -3818   VWT = -4077

PHIDX = +3194.5
SQ3 = .0085

2b

FIGURE 2 SQ3 RUNS; DECEMBER 1983

All recorder Channels set to 5 volts/line
VWP, VWT, and PHIDX expressed in radians/second

Assuming an elliptical whirl orbit at steady state (Alpha small) as shown in Figure 3 and reorienting our coordinate axis to place the ellipse semi-major axis along z, we define:

$$
\begin{aligned}
y &= A_y \sin(\omega t) & &y,z \text{ represent displacement} \\
z &= A_z \cos(\omega t) & &\omega \equiv \text{ vibration frequency} \\
\dot{y} &= A_y \,\omega \cos(\omega t) & & \\
\dot{z} &= -A_z \,\omega \sin(\omega t) & &
\end{aligned}
\tag{1}
$$

Substituting Equations 1 into the hybrid simulation defined whirl velocity,

$$
\begin{aligned}
VW &= \frac{y\dot{z} - \dot{y}z}{y^2 + z^2} \\
&= \frac{-A_y A_z \omega}{A_y^2 \sin^2(\omega t) + A_z^2 \cos^2(\omega t)} .
\end{aligned}
\tag{2}
$$

The maximum value of VW occurs when y=0,

$$VW_{max} = \frac{-A_y}{A_z} \omega . \tag{3}$$

When z=0, VW attains its minimum value

$$VW_{min} = \frac{-A_z}{A_y} \omega . \tag{4}$$

Combining Equations 3 and 4,

$$\omega = \sqrt{VW_{max} \; VW_{min}} . \tag{5}$$

If the arithmetic mean of VW_{max} and VW_{min} is used to approximate the unstable whirl velocity, from Equations 3 and 4 we get

$$1/2\ (VW_{max} + VW_{min}) = 1/2\ (x + \frac{1}{x})\ \omega$$

$$\text{where } x = \frac{-A_z}{A_y} \quad . \tag{6}$$

The geometric mean produces a better estimate of the actual whirl orbital velocity.

Analysis of Omega from the strip chart recorder is illustrated in Figure 4a using VWT. The distance indicated by arrow 1 is VW_{min}; arrow 2 is VW_{max}. At points after the transient vibrations die out (approximately point 3) measurements of VW_{min} and VW_{max} are made in .01 inch increments. The values are substituted into Equation 5 to get the whirl velocity. To minimize reading errors, we obtain a mean Omega from between five and ten points.

The derivation of the relationship between Alpha, the damping coefficient of the response amplitudes and those amplitudes is as follows:

We assume

$$y = e^{-\alpha t} \sin\ (\omega t - \phi) \tag{7}$$

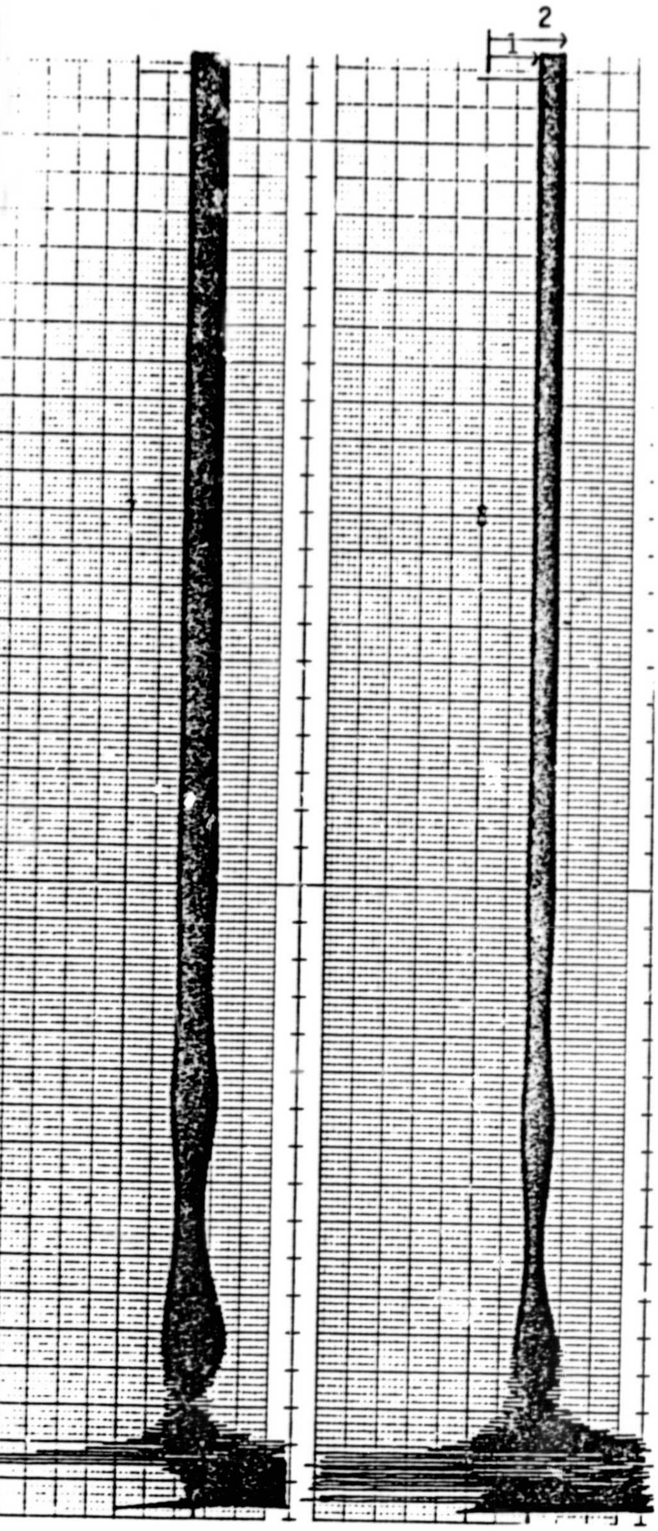
Where:

$y \equiv$ displacement in y direction

$\alpha \equiv$ damping coefficient

$\omega \equiv$ whirl velocity

$\phi \equiv$ phase angle

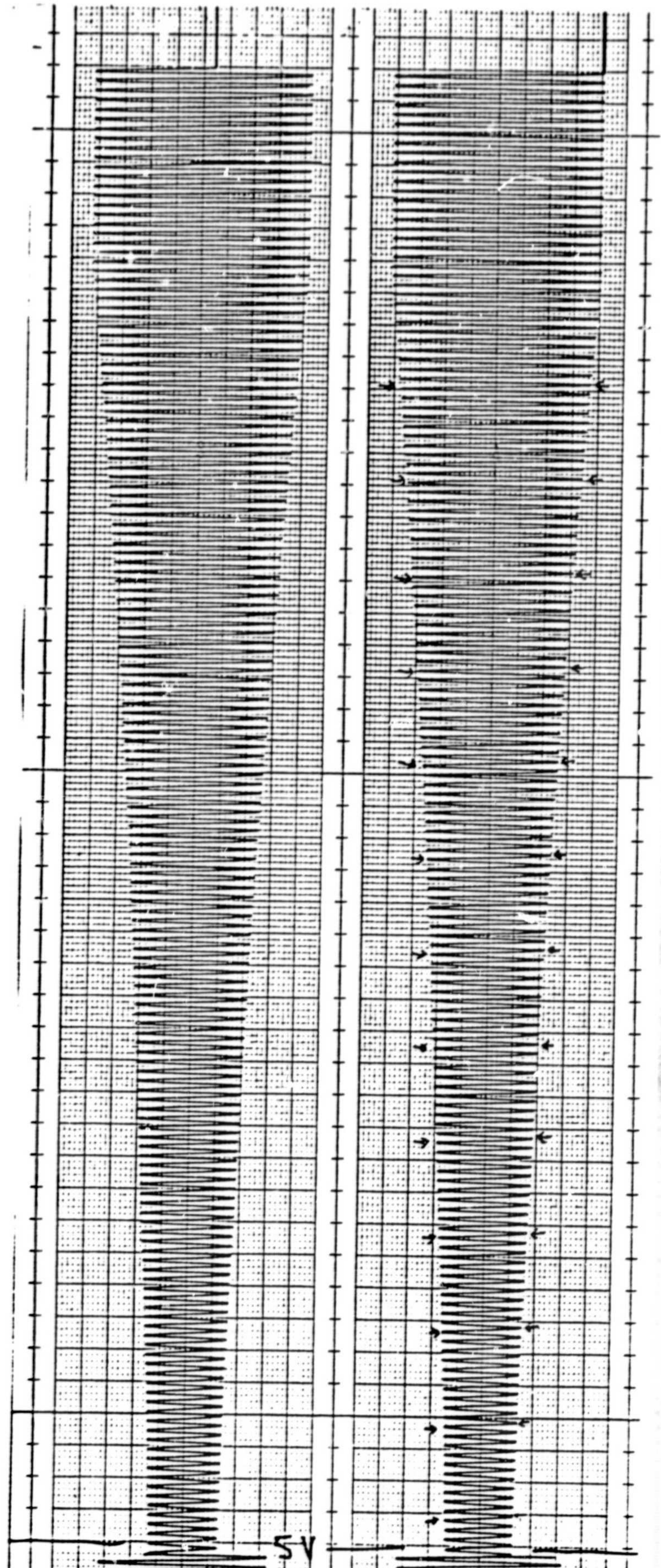


VWP VWT

2 v/line
.2 mm/sec
PHIDX = -3194.5

4a Recorder #2, Channels 23 and 24

FIGURE 4 STRIP CHART RECORDS



DEAY 5 v/line DEAZ
.5 mm/sec
PHIDX = -3194.5
4b Recorder #1, Channels 11 and 12

Displacement peaks occur at

$$Y = P = e^{-\alpha t} \qquad \text{when } \sin(\omega t - \phi) = 1.$$

The ratio of displacement of any peak, P_1, and peak Pn, the n^{th} peak from P_1 is:

$$\frac{Pn}{P_1} = \frac{e^{-\alpha(t + \frac{2\pi n}{\omega})}}{e^{-\alpha t}} \tag{8}$$

$$= e^{-\alpha \frac{2\pi n}{\omega}}$$

The damping coefficient, Alpha, is defined in terms of the damping ratio, ζ

$$\alpha = \frac{\zeta\omega}{\sqrt{1 - \zeta^2}} \tag{9}$$

Substituting Equation 9 into Equation 8,

$$\frac{P_n}{P_1} = e^{-2\pi\zeta n} \quad . \tag{10}$$

Solving for ζ,

$$\zeta = \frac{1}{2\pi n} \ln \frac{P_1}{P_n} \tag{11}$$

And substituting into Equation 9,

$$\alpha = \frac{\omega \ln \frac{P_1}{P_n}}{\sqrt{4\pi^2 n^2 - (\ln P_1/P_n)^2}} \quad . \tag{12}$$

The magnitude, R, and the phase angle, ϕ, are calculated from their definitions:

$$R = \sqrt{\alpha^2 + \omega^2} = \frac{\omega}{\sqrt{1 - \zeta^2}} \tag{13}$$

$$\phi = \tan^{-1} \frac{\omega}{\alpha} \tag{14}$$

Figure 4b is used to illustrate analysis of the damping coefficient. The speed of recorder #1 with channels 11 and 12 has been increased to .5 mm/sec and the voltage settings set to 5 volts/line, making the peaks larger and more distinct for easier measurements. In this case the peak to peak amplitude (indicated by arrows) is measured every tenth peak. Twelve amplitudes are measured, the last amplitude (P_{10}) of one ratio becoming the first amplitude (P_1) of the next. Twelve ratios are calculated and substituted into Equation 12 using n=10 and Omega from Figure 4a. The mean of the twelve values is Alpha.

2.2 ERROR ANALYSIS

The hybrid simulation verification process inevitably led us to a need to determine "how good is good enough." Several possible sources of error in the hybrid simulation results were identified and addressed: data reading and subsequent compounded error, digital to analog conversion error, and zero drift of the recorder. In addition, differences between the stability model and hybrid simulation results that may be due to numerical integration and the use of single precision arithmetic were investigated.

The error margin was computed for the case labeled BETB to obtain a rough estimate of errors generated when reading strip chart recorders and analyzing data. The greatest possible errors for each computed variable (as defined in Equations 5, 12, 13, 14) are listed in Table 1, columns 3 and 4. Values in table 1 were calculated when we were using the arithmetic mean to estimate Omega. Consequently, some values differ from elsewhere in this report

TABLE 1 CASE "BETB" ERROR (BETA = .5)

Variable	Mean	+/-	Error (%)	St. Dev. (%)
Alpha	4.69	1.33	28.26	16.32
Omega (RPM)	-20095.83	251.15	1.25	1.13
Magn (RPM)	-20095.83	26.30	1.25	—
Phase (DEG)	89.87	.04	4.24	—

The errors in columns 3 and 4 include reading error (based on $\pm.005$ inches) and compounded error in results. The standard deviations of Alpha and Omega for BETB are listed in column 5 for comparison with the estimated error. As seen in Equation 13, Omega dominates the equation for calculating the magnitude.

Consequently, the calculated standard deviations of magnitude and phase were less than .1% in this case.

It is important to note that a displacement of .01 inches in VWP or VWT channels used to calculate Omega, represent 1492 RPM (156.25 rad/sec) when the recorder is set to 5 volts/line. When it is set to 2 volts/line, as in case BETB, a .01 inches displacement represents 597 RPM (62.5 rad/sec). The width of the pen line is approximately .01 inches as are the lines that represent midpoint on the recorder paper. It is difficult for the evaluator to discern much less than that. Fortunately the whirl velocity curves are characterized by bar type appearances that facilitate easy reading. In this case pen line width does not affect the value of the whirl velocity as greatly as the point within the zero line from which the measurements are read. To minimize errors it is essential to calculate the mean of several readings using the midpoint of the centerline. It is with such careful analysis that results of Table 1 were obtained.

Because Alpha is calculated from a ratio of measurements the problem of placement of zero does not dominate the error analysis. However, we no longer have the simple bar like appearance of VWP or VWT. Now the width of the pen line is more important. Again a mean value is fundamental to the reliability of the values derived from strip chart recorder measurements.

The digital to analog conversion error was checked by sending a specified voltage to each channel and verifying pen movement. Initially a need for recalibration was indicated. All data in this report (except Table 1) were taken after recalibration and show only small differences between results before recalibration. Subsequent checks indicated conversion error less than 5% on every channel with most channels indicating negligible error. Because they are used

for absolute measurements, the channels of primary importance for verification runs are numbers 23 and 24 (VWP,VWT), both of which measured less than 1% error.

No zero drift was observed on either channels 23 or 24 during the error analysis. In later runs however, as much as .01 inches has been noticed. It is wise to check zero drift periodically on channels carrying absolute data information.

A simulation was developed on Control Dynamics' PDP 11/23 to isolate the effects of the integration scheme and single precision mathematics used in the hybrid simulation. Modal damping, stiffness and mode shapes calculated by the stability model code are input to the digital simulation. The simulation output is compared to stability model results run with the same modal input. Any discrepancies can be credited to the mathematical methods.

Figures 5a and 5b are examples of the digital simulation graphics output. Figure 5a is the displacement amplitude at the Alford/Turbine Seal. Alpha analysis is exactly as explained in Section 2.1 for hybrid simulation output. Figure 5b is a cross plot of displacements at the turbine end of the rotor. To get the frequency from this plot, it is necessary to know the time interval over which points are plotted. The number of cycles are counted and the ratio, cycles/time, converted to radians/second for direct comparison with stability model output.

A sample of results of the PDP simulation is listed in Table 2 along with stability model results. The small discrepancies represent error due to integration and single precision calculations. At higher frequency whirls, such as those seen here, larger differences are expected (see Reference, page 10).

TABLE 2 PDP SIMULATION RESULTS; SQ3 = -.0071

	Simulation	Stability Model
Alpha	19.71	18.46
Omega	4117	4102

In summary we can say that digital to analog conversion errors, zero drift, numerical integration and single precision arithmetic contribute minimal errors in results. The error in our estimate of Omega can be as much as 1000 to 2000 RPM at 5 volts/line or 500 to 1000 RPM at 2 volts/line. Errors in this range can easily arise from reading charts at an angle or from zero drift. However, the mean error for a particular value is usually much smaller because errors are minimized by careful reading of a large data set and frequent checks of zero drift. If results are questionable and greater accuracy is required, the operator should evaluate the sources of error to determine an error band for the particular run or read data from a digital data scan using the data taking option on the hybrid.

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Figure 5a Y Displacement at Alford Seal

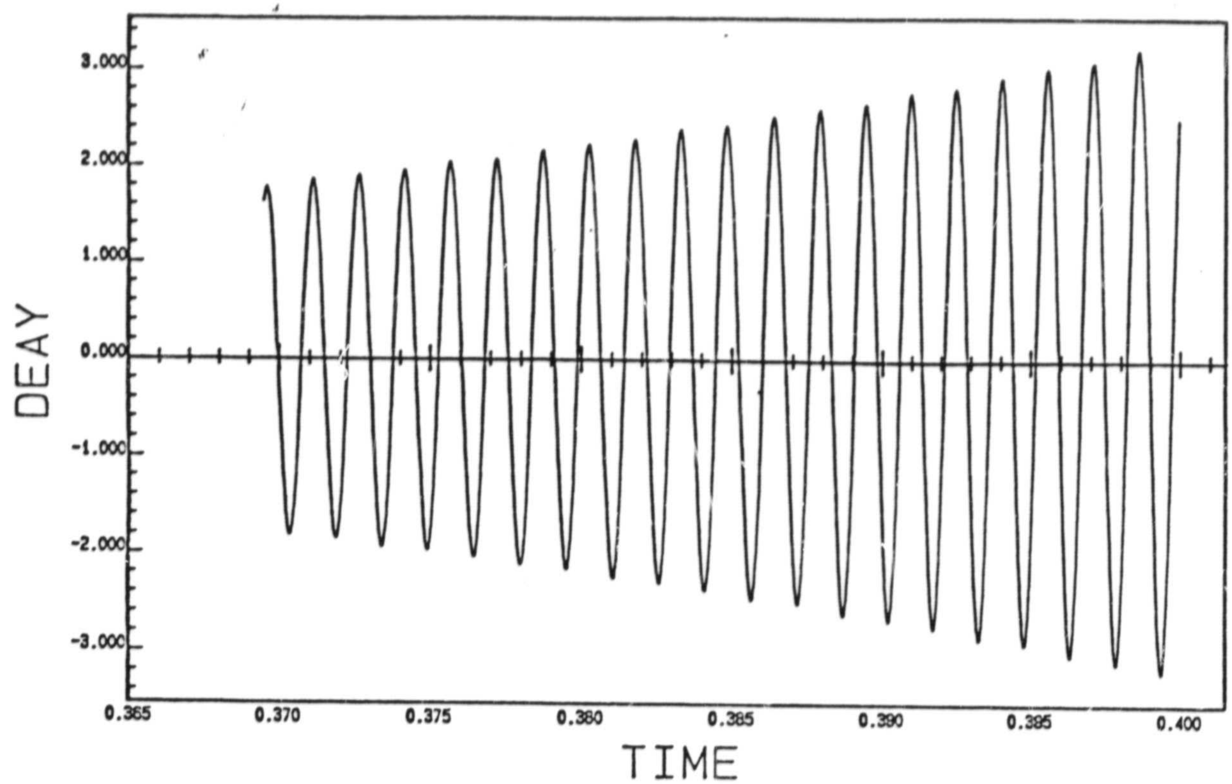


Figure 5b Displacement at Turbine End Bearings

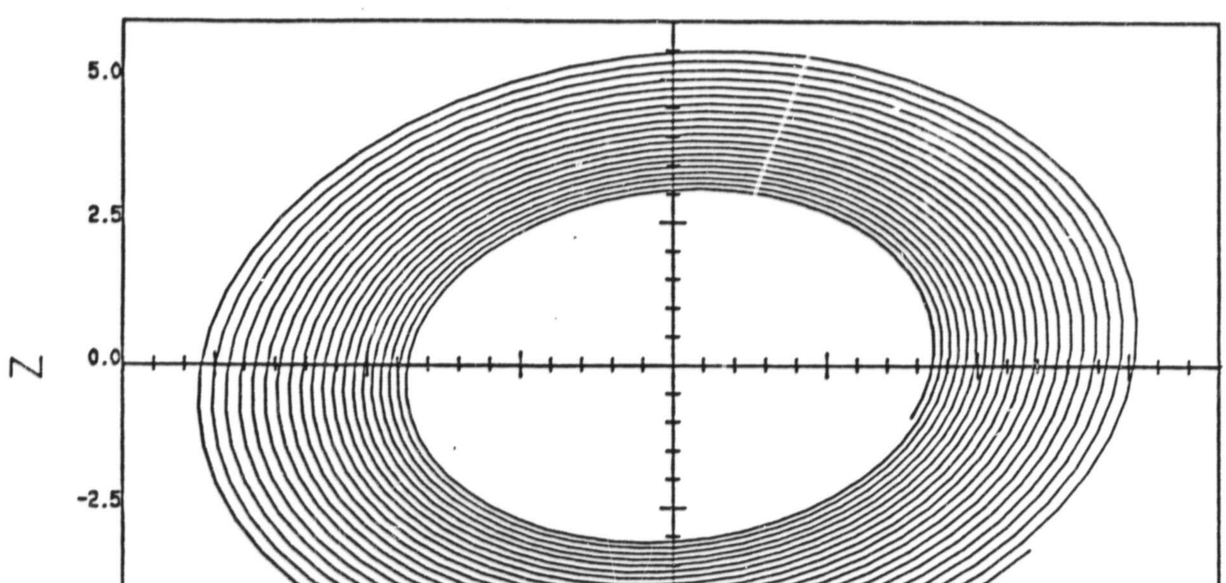


FIGURE 5 PDP SIMULATION RESULTS

2.3 INPUT DATA DISCREPANCIES

In May of 1983 a new set of structural modes and frequencies for the LOX pump housing were provided by Rocketdyne and input to the SSME turbopump hybrid simulation. Because of the large volume of data required to specify the parameters of the models, it is conceivable that discrepancies between input data of hybrid and linear stability models could easily occur. To investigate data input discrepancies, we made an extensive comparison between the two sets.

Table 3 lists the input data discrepancies found. With the exception of the sign of the case mode displacements, the stability model data has been changed to match that of the simulation values listed in Table 3. Case mode displacements used in the stability model must be the negative of those used in the hybrid because of the different way in which they are used by these programs. The stability model results are different in the fourth and fifth decimal place from output generated before the changes were made.

The bearing dynamics are modeled as a piecewise linear spring with two break points in the stiffness curve. These break points correspond to the inner and outer deadbands (see Reference, page E-18). When the deadbands are set to zero, the hybrid simulation code nullifies the effect of bearing deadbands. On the stability model the parameters affected by the deadbands must be set to zero manually when deadbands are eliminated. Consequently, KTDB, the bearing stiffness between the deadbands on the stability model must be changed from its nominal value of 77,000 to zero for cases which will be compared to hybrid runs with zero deadbands. The stability model results changed in the second decimal place after KTDB was set to zero. All stability model results in this report were run with KTDB = 0 unless otherwise noted.

Table 3 DATA INPUT DISCREPANCIES

Variable	Hybrid Simulation	Stability Models
Second Alford curve fit coefficient	.7344541	.5261
Case mode Y displacements	.824220	-.7791
	-.021071	.038538
	-.671020	.51947
	-.030111	.035695
	-.027291	.00034801
	.041627	-.01821
	.6063	-.33281
	-.038184	.030607
	.3235	-.17948
	-.18238	.11765
Case mode Z displacements	.010491	-.00918561
	-.89823	.7987
	-.15703	.14642
	.58229	-.46759
	-.30329	.23216
	.38196	-.26784
	-.1997	.12995
	.4776	-.19665
	-.17592	.14643
	-.63293	.37902
Rotor mode displacements		
P	-1.58715	-1.58458
T	1.45654	1.45273
A	-.786938	-.787191
B/S3	1.85618	1.85881
S1	.08023274	.08024846
S2	-4.39593	-4.398109
Case frequencies	284.062	284.07
	538.217	538.27
	700.323	700.36
	1888.030	1881.21
	1948.350	1948.50
	2207.410	2207.58
	2713.520	2713.70
	2943.290	2943.54
	3065.380	3065.62
	3408.060	3408.31

2.4 SIMULATION ERRORS

A detailed inspection of the simulation code was made to uncover any discrepancies that may have accounted for observed differences in behavior between hybrid and stability models. Two very minor errors were discovered in the simulation code listed in Appendix A. The stiffness coefficient at the Alford seal location (KSA) is not declared real causing it to be truncated to an integer value. The declaration should occur at or near line 74. The relative displacement from centerline between rotor and case with the outer deadband removed (DPP) should be a factor in the multiplication of the deadband stiffness coefficients according to Reference, page E-18, Equations 40. This multiplication should occur in lines 731 - 746 of the code. The truncation of KSA does not affect results significantly. Results in this report are run with deadbands set to zero.

Recently Mr. Steve Ryan of the MSFC Systems Dynamics Laboratory Control Systems Division Vehicle Stability Branch discovered an error in the rotor equations of motion involving the rotor rotational acceleration, $\ddot{\phi}_x$. It is necessary to rederive the rotor equations of motion to display this error. The derivation will start from the kinetic energy expression for the ith rotor element given in Reference, page E-7.

$$T_i = \frac{1}{2} M_i \left(\dot{X}_i^2 + \dot{Y}_i^2 + \dot{Z}_i^2\right) + \frac{1}{2} I_{ai}\omega_{xi}^2 + \frac{1}{2} I_{ti}\left(\omega_{yi}^2 + \omega_{zi}^2\right)$$

$$\underline{\omega}_i = \begin{matrix} \dot{\phi}_{xi} + \dot{\phi}_{yi} \sin\phi_{zi} \\ \dot{\phi}_{yi} \cos\phi_{xi} \cos\phi_{zi} + \dot{\phi}_{zi} \sin\phi_{xi} \\ -\dot{\phi}_{yi} \sin\phi_{xi} \cos\phi_{zi} + \dot{\phi}_{zi} \cos\phi_{xi} \end{matrix}$$

To linearize the resulting system of equations, we reduce the kinetic energy to second order equation in the assumed small quantities, ϕ_{yi}, ϕ_{zi}, $\dot{\phi}_{yi}$, $\dot{\phi}_{zi}$. The resulting kinetic energy is

$$T_i = \frac{1}{2} M_i \left(\dot{X}_i^2 + \dot{Y}_i^2 + \dot{Z}_i^2\right) + \frac{1}{2} I_{ai} \left(\dot{\phi}_{xi} + \dot{\phi}_{yi}\, \phi_{zi}\right)^2 + \frac{1}{2} I_{ti} \left(\dot{\phi}_{yi}^2 + \dot{\phi}_{zi}^2\right) \tag{16}$$

The forces and torques acting on this body can be incorporated into the model through the virtual work principle. The work done in a virtual displacement of the body is given by

need to be upper case & moved up

$$\delta W = \left(F_{xi}\delta X_i + F_{yi}\delta y_i + F_{zi}\delta z_i\right) + T_{xi}\left(\delta\phi_{xi} + \phi_{zi}\delta\phi_{yi}\right) + T_{yi}\,\delta\phi_{yi} + T_{zi}\,\delta\phi_{zi} \tag{17}$$

Some discussion of these terms needs to be made here. This expression differs from Equation 26, page E14 of Reference, in the additional term which multiplies T_{xi}. The extra term is carried along because we allow T_{xi} to be large while restricting T_{yi} and T_{zi} to be small.

The resulting equations of motion for body i are

$$M_i \begin{bmatrix} \ddot{X}_i \\ \ddot{Y}_i \\ \ddot{Z}_i \end{bmatrix} = \begin{bmatrix} F_{xi} \\ F_{yi} \\ F_{zi} \end{bmatrix}$$

$$I_a\, \ddot{\phi}_{xi} = T_{xi} \tag{18}$$

$$\begin{aligned} I_{ti}\, \ddot{\phi}_{yi} + I_{ai}\, \dot{\phi}_{xi}\, \dot{\phi}_{zi} + I_{ai}\, \ddot{\phi}_{xi}\, \phi_{zi} &= T_{yi} + T_{xi}\, \phi_{zi} \\ I_{ti}\, \ddot{\phi}_{zi} - I_{ai}\, \dot{\phi}_{xi}\, \dot{\phi}_{yi} &= T_{zi} \end{aligned} \tag{19}$$

Since $I_{xi}\ \ddot{\phi}_{xi} = T_{xi}$, we can simplify these equations somewhat by using this result in the ϕ_{yi} and ϕ_{zi} equations. We obtain:

$$
\begin{aligned}
M_i\ddot{X}_i &= F_{xi}\\
M_i\ddot{Y}_i &= F_{yi}\\
M_i\ddot{Z}_i &= F_{zi}
\end{aligned}
\tag{20}
$$

$$
\begin{aligned}
&I_{ai}\ \ddot{\phi}_{xi} = T_{xi}\\
&I_{ti}\ \ddot{\phi}_{yi} + I_{ai}\ \dot{\phi}_{xi}\ \dot{\phi}_{zi} = T_{yi}\\
&I_{ti}\ \ddot{\phi}_{zi} - I_{ai}\ \dot{\phi}_{xi}\ \dot{\phi}_{yi} = T_{zi}
\end{aligned}
\tag{21}
$$

We now make the substitutions shown below:

$$
\begin{aligned}
X_i &= X + \textstyle\sum_j \Phi_{ijx}\xi_j\\
Y_i &= Y + \textstyle\sum_j \Phi_{ijy}\xi_j\\
Z_i &= Z + \textstyle\sum_j \Phi_{ijz}\xi_j\\
\phi_{xi} &= \phi_x + \textstyle\sum_j \Psi_{ijx}\xi_j\\
\phi_{yi} &= \phi_y + \textstyle\sum_j \Psi_{ijy}\xi_j\\
\phi_{zi} &= \phi_z + \textstyle\sum_j \Psi_{ijz}\xi_j
\end{aligned}
\tag{22}
$$

To derive the working equations of motion we make two further assumptions. First, the rotor modal functions $\underline{\Phi}_{ij}$ and $\underline{\Psi}_{ij}$ satisfy axial symmetry and planar symmetry properties. Second, the forces and torques consist of the driving torque T_x acting only at the turbine stages, the internal forces and torques which define the rotor mode shapes $\underline{\Phi}_{ij}$ and $\underline{\Psi}_{ij}$, and the imbalance forces and torques. The resulting equations are:

$$\ddot{X} = \frac{1}{M} \sum_i F_{xi}$$

$$\ddot{Y} = \frac{1}{M} \sum_i (F_{yi} + F_{uyi}) \tag{23}$$

$$\ddot{Z} = \frac{1}{M} \sum_i (F_{zi} + F_{uzi})$$

$$\ddot{\phi}_x = T_x/I_1$$

$$\ddot{\phi}_y = -\dot{\phi}_x \frac{I_1}{I_2} \dot{\phi}_z - [\dot{\phi}_x \Gamma_o \dot{\xi}_y + \sum_i \ell_i (F_{zi} + F_{uzi})]/I_2 \tag{24}$$

$$\ddot{\phi}_z = \dot{\phi}_x \frac{I_1}{I_z} \dot{\phi}_y - [\dot{\phi}_x \Gamma_o \dot{\xi}_z - \sum_i \ell_i (F_{yi} + F_{uzi})]/I_2$$

$$\ddot{\xi}_y = -2\zeta_R \Omega_R \dot{\xi}_y + \dot{\phi}_x \Gamma_o \dot{\phi}_y - \dot{\phi}_x \Gamma_1 \dot{\xi}_z - \dot{\phi}_x 2\zeta_R \Omega_R \xi_z - \Omega^2_R \xi_y + \sum_i \phi^2_i (F_{yi} + F_{uyi})$$

$$\ddot{\xi}_z = -2\zeta_R \Omega_R \dot{\xi}_z + \dot{\phi}_x \Gamma_o \dot{\phi}_z + \dot{\phi}_x \Gamma_1 \dot{\xi}_y + \dot{\phi}_x 2\zeta_R \Omega_R \xi_y - \Omega^2_R \xi_z + \sum_i \phi^2_i (F_{zi} + F_{uzi}) \tag{25}$$

The forces F_{yi} and F_{zi} are external forces such as bearing and seal forces. Fu_{yi} and Fu_{zi} are forces due to rotor imbalances. All forces are calculated as derived in Reference.

In summary, the only changes to the rotor equations shown in Reference, page E17, Equation 37, is that all the terms on the right hand side of the equality which contained $\ddot{\phi}_x$ have been eliminated. The resulting change to simulation dynamics should be minimal, since typical imbalance forces are of order $(2500)^2$ (10^{-4}) compared to (2500)(.001), i.e. 600 to 3. Here we have assumed typical rotor speeds of 2500 radians/sec, typical imbalances of 10^{-4} lb sec^2,

typical ramp rates of 2500 radians/sec, and typical values of I_1 on the order of unity. Thus in the range of speeds of interest, the erroneous terms are less than ten percent of the imbalance forces. As a consequence, we feel that the effects of these extra terms on predictions derived from the hybrid simulation have been negligible. We do recommend correcting the simulation at the earliest opportunity.

After changing the input data of the stability model and taking those errors found in the simulation code into account, we still saw discrepancies when comparing the whirl orbital frequencies (Omega) and damping coefficients (Alpha) predicted by the linear stability model with those observed from linear simulation results. Good agreement of stability boundaries, Omega and Alpha was observed when the cross coupling coefficients SQA and SQ1 are varied (Table 4, column 1). There was also adequate agreement between the two programs for BETA and ZER runs. However, variations in SQ2 and SQ3 were producing discrepancies far beyond the limit of acceptable error. The whirl frequencies of the hybrid simulation for SQ2 = .005 was 13% larger than that of the stability model. Although the frequency at which SQ3 goes unstable was closer to the predicted value, the damping coefficient predicted by the stability model was -32.00 but observed to be .87 on hybrid.

After a thorough investigation of the hybrid simulation and unable to fully explain the remaining differences, we ran the stability model with the rotor modal mass integral (GAMO), a gyroscopic cross coupling coefficient, set to the negative of its nominal value of -.261505. This was done late in the study as a final attempt to understand the remaining discrepancies and verify that a previously identified correction had been made. The final report of Contract Number NAS8-34924 written in October 1982 (Reference, Section 2.1), recommends

TABLE 4. STABILITY MODEL - HYBRID SIMULATION RESULTS

	STABILITY MODEL GAMO = -.2615050		HYBRID SIMULATION GAMO = NOMINAL		STABILITY MODEL GAMO = .2615050	
Parameter Value[1]	Alpha[2]	Omega[3]	Alpha	Omega	Alpha	Omega
SQ1 = .0022	5.61	-2068	.52	-2011	.35	-1961
SQ2 = .005	.70	-4169	5.60	-4719	4.53	-4650
SQ3 = .0071	-32.00	-4179	.87	-4132	.1	-4160
SQA = .0019	9.09	-2068	3.08	-2083	2.53	-1960
BETA = .5	11.03	-2068	4.08	-2004	3.89	-1959
ZER = .15	6.39	-2070	8.49	-2003	15.02	-1958

1. Parameter value chosen is that at which hybrid simulation goes unstable.

   Nominal Values: SQ1 4.51 E-4
   SQ2 1.576 E-3
   SQ3 1.097 E-3
   SQA 9.453 E-4
   BETA 0.0
   ZER 0.005

2. Alpha is the real part of the stability model unstable root and the damping coefficient from the hybrid.

3. Omega is the imaginary part of the stability model unstable root and the whirl frequency from the hybrid. The values here are in rad/sec.

that the sign in the equations using the parameter GAMO be changed. Under that contract we had determined that the sign of the GAMO term as used in the hybrid was opposite the sign used in the stability model. The stability model sign was verified to be correct by comparison with the derived equations of motion. It was later determined that the version of the simulation being used for verification was not the same as the current version used for production runs in which the sign of the GAMO term had been corrected. The correction was verified by repeating our check cases with the production version of the simulation and noting the response. At that time we concluded that the production version of the simulation had the proper sign of the GAMO term. The latest listing of the hybrid simulation code (lines 827 - 844) supports the verification checks run at the late stages of the earlier contract. Thus, until all other possibilities were eliminated, it did not occur to us to reexamine the sign of this term in the current verification effort. We were surprised to see that reversing the sign of this quantity as used in the hybrid simulation compared to the stability model brought the SQ2 comparison cases to good agreement while maintaining or improving agreement in all the other comparison cases.

Not only does this resolve the SQ2 frequency discrepancies to well within accepted error values, but it also improves agreement between damping coefficients and whirl frequency values of the stability model and those of the hybrid simulation for cross coupling at the other seals. As would be expected, the stability model is more stable (with one exception) than the simulation when the value of GAMO is used in the linear stability model is set to the negative of its proper value to agree with the hybrid model. The numerical integration scheme used in the hybrid is expected to be somewhat less stable, but results for nominal GAMO were not dependably so.

Three hybrid runs were made with SQ2 = .005 to examine the simulation response to positive and negative GAMO. The whirl velocities are listed in Table 5. With the stability model results in Table 4, these runs prove convincingly that GAMO is implemented with the incorrect sign in the current production version of the hybrid simulation. It is possible this occurred when the latest set of structural data was installed.

TABLE 5. GAMO VERIFICATION RUNS (SQ2 = .005)

GAMO	OMEGA (rad/sec)
Nominal	-4731
.261505	-4295
-.261505	-4759

2.5 SIMULATION RESPONSES

During our verification efforts, we noticed several hybrid simulation peculiarites. The problems were inconsistent indicating that the cause was not in the simulation code. The most likely source is hardware although in these incidents, there were no run time error messages or malfunctions noticed. Diagnostics did not indicate any other problems. This section, therefore is more for completeness of our report than to point out any simulation errors.

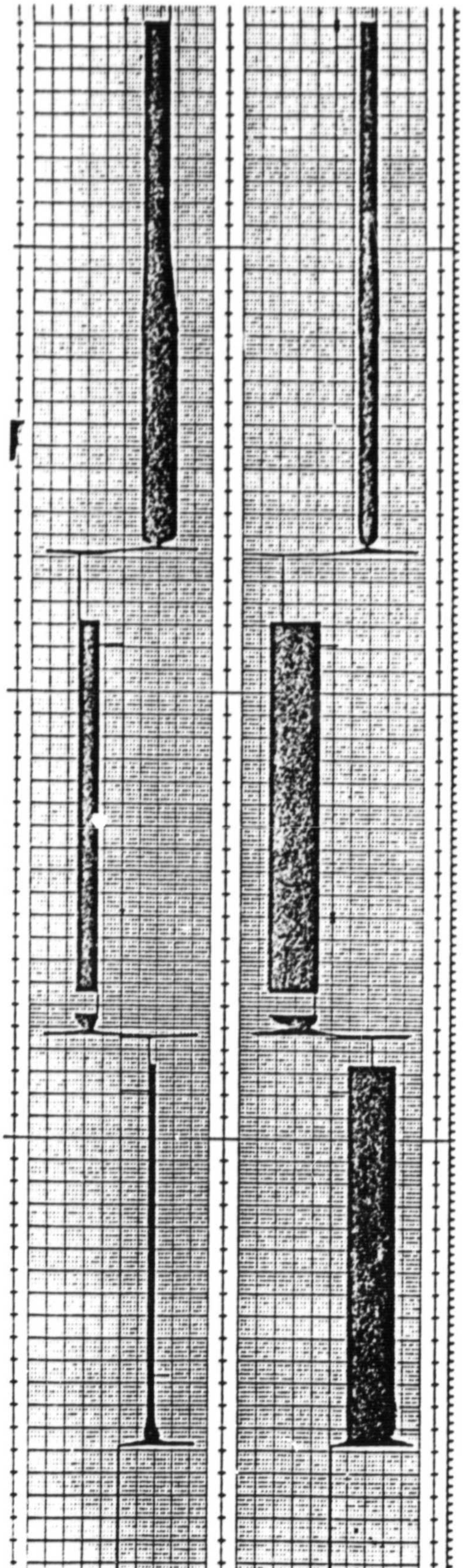
In August there arose a question concerning the sign of PHIDX, the rotor spin angular velocity. The seal coefficients are expressed as polynomial functions of the shaft spin speed called PHIDX. Since PHIDX is negative for the LOX pump the absolute value of PHIDX is used in these polynomials. The cross coupling coefficients should be multiplied by the negative sign of PHIDX as their affect opposes the rotor velocity (see Reference, E-17, Equation 37). We could not find the multiplication in our copy of the code.

As a result of the forms of the equations and the way in which the model coefficients are calculated from PHIDX, the hybrid simulation should behave identically except for changes in the direction of induced whirls when rotor spin direction is reversed. Test cases run in September with all destabilizers except SQ3 set to nominal failed to produce the symmetry in whirl velocity magnitudes for +/- PHIDX. Testing the other parameters with +/- PHIDX produced symmetrical whirl velocities. Relative to results we were observing for SQ2 stability-hybrid comparison runs, the output was close to the outside of our error margin so we turned our efforts to the more alarming discrepancies in SQ2 that we later found to be due to the GAMO error.

In late December we returned to the PHIDX sign problem. To insure proper treatment of the cross coupling coefficients, we checked the response of the simulation to reversed shaft speed (PHIDX) and reversed cross coupling coefficients at each of the seals. All destabilizers (SQ1,SQ2,SQ3,SQA,BETA, and ZER) except the parameter of interest were set to zero in order to isolate its effect. Four runs at an unstable coefficient value were made for each parameter; +/- cross coupling coefficient and +/- PHIDX. We were looking for proper response in direction and magnitude of the whirl velocity. The whirl velocities responded correctly in direction for sign reversals at unstable values of SQ1, SQ2, AND SQA. For an unstable value of SQ3 and PHIDX greater than zero the whirl velocity did not reverse direction until it had built to amplitudes too large to measure.

Because of the discrepancies in these results, the SQ3 test (with all other destabilizers set to zero) was run once more in February (Figure 6). This time the whirl velocity responded correctly in direction. Magnitude differences were no greater than 1480 RPM. This run is the most reliable. Although our test cases did not produce questionable results at the beginning of the September and December sessions in which the SQ3 runs were made, other runs on those days indicated possible hardware or system software malfunctions. These problems that were seemingly circumvented are enough to seed doubt in those results. The "cleanness" of the February result provides us with additional reason to disregard the earlier results.

Our data indicates that the sign change in PHIDX is being treated correctly in the calculation of the simulation parameters from the curve fitting polynomials. We cannot verify this by inspection of the simulation listing but note that it is apparently being done and are content with that.



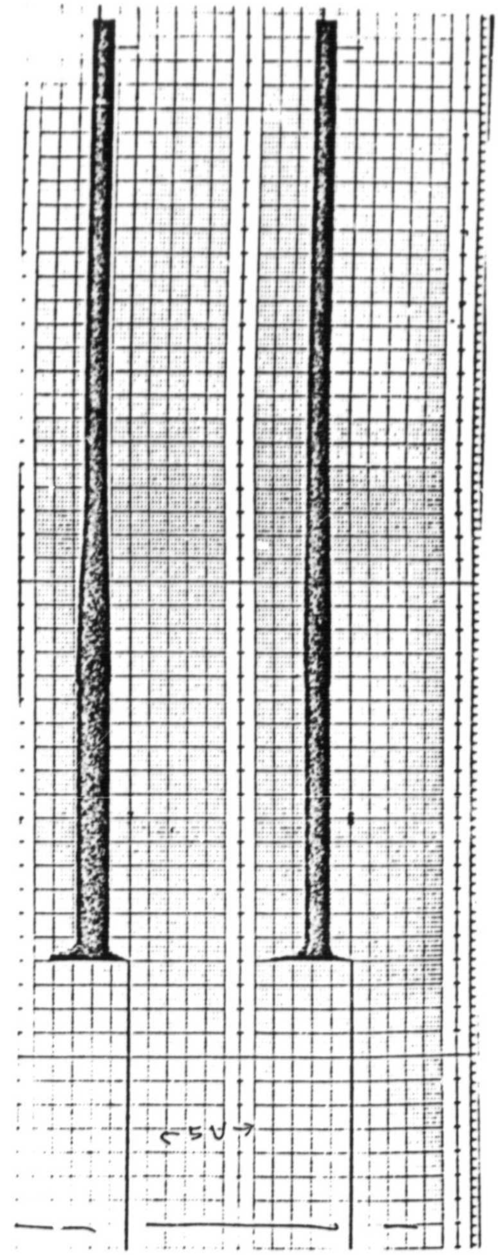
← Figure 6d
VWP = -4105
VWT = -4254
SQ3 = -.0085
PHIDX = 3194.5
2 v/line

Figure 6c →
VWP = 4259
VWT = 3805
SQ3 = -.0085
PHIDX = -3194.5
5 v/line

← Figure 6b
VWP = 4429
VWT = 3906
SQ3 = .0085
PHIDX = 3194.5
2 v/line

← Figure 6a
VWP = -4285
VWT = -4433
SQ3 = .0085
PHIDX = -3194.5
2 v/line

VWP VWT



VWP VWT

FIGURE 6 SQ3 VERIFICATION RUNS;
FEBRUARY 1984

VWP, VWT, and PHIDX expressed in rad/sec

We investigated hybrid simulation repeatability in October. This was done by rerunning several cases using identical parameters. Excellent results were obtained for BETA and SQ3 comparisons. SQ2 results were not as good (Table 6a).

To find the stability boundary often requires several run time inputs; the simulation is suspended while the operator enters a new parameter value. The parameter is changed from unstable to stable values, then to an unstable value closer to the boundary. The process is repeated iteratively until the stability boundary is found without letting the system go unretrievably out of control. What we will call "cold start" runs are those data runs not preceeded by any run time inputs.

For cold starts the SQ2 results are within acceptable error margins (Table 6b). The data in itself does not indicate whether the problem is due to SQ2 or hysteresis. Rerunning the simulation with a positive GAMO may produce more conclusive results. From Table 4 it is evident that GAMO does not affect all parameters to the same degree, alghough one would expect it would affect all runs of one parameter similarly. From these results, we must assume that there is no connection between earlier SQ2 hybrid vs. stability model discrepancies and the relatively large standard deviation between hybrid runs.

TABLE 6a COMPARISON OF WHIRL VELOCITY

Parameter	Run Date	OMEGA (RPM)	Run Date	OMEGA (RPM)	%Dif
Beta=3.0	8/30	-16644	10/19	-16664	.12
SQ3=.0071	9/6	-39458	10/20	-39515	.15
SQ2=.005	9/6	-46028	10/20	-43354	6.16

TABLE 6b COMPARISON OF VW (RPM); SQ2 = .005, COLD STARTS

11/10	11/28	11/28	Mean	St. Dev.	%
45636	44853	45436	45311	407	.90

3.0 FILTER

We have developed a real time adjustable filter that is capable of filtering Y or Z displacements at any joint to find the dominant whirl frequency. The damping coefficient can also be derived from the filter output. The filter uses a running Fourier coefficient algorithm. The derivation of the algorithm is included in Sec. 3.1. Section 3.2 explains the use of the program and presents some examples. The FORTRAN Code is listed in Appendix C.

3.1 FOURIER FILTER ALGORITHM

A sampled function f(t) that is periodic with a period of $\tau = N\Delta t$ can be represented as a Fourier series

$$f(t) = \sum_{k=0}^{\infty} \left(a_k \cos \frac{2\pi kt}{\tau} + b_k \sin \frac{2\pi kt}{\tau}\right) \tag{26}$$

where

$$a_k = \sum_{n=0}^{N} f(t_n) \cos \frac{2\pi kn}{N}; \; t_n = n\,\Delta t$$

$$b_k = \sum_{n=0}^{N} = f(t_n) \sin \frac{2\pi kn}{N} \quad . \tag{27}$$

For convenience, let

$$f_n \equiv f(t_n)$$

$$C_{k,n} \equiv \cos \frac{2\pi kn}{N} \text{ and } S_{k,n} \equiv \sin \frac{2\pi kn}{N} \quad . \tag{28}$$

At a time $t' = t + \Delta t$,

$$a_k' = \sum_{n=0}^{N} f_{n+1} C_{k,n}$$

$$b_k' = \sum_{n=0}^{N} f_{n+1} S_{k,n} \tag{29}$$

Manipulating Equations 29:

$$a_k'C_{k,1} - b_k'S_{k,1} = \sum_{n=0}^{N} f_{n+1} \left(C_{k,n} C_{k,1} - S_{k,n} S_{k,1}\right)$$

$$= \sum_{n=0}^{N} f_{n+1} \quad C_{k,n+1}$$

$$= a_k - f_o \; C_{K,0} + f_{n+1} \; C_{k,n+1}$$

$$a_k'S_{k,1} + b_k'C_{k,1} = \sum_{n=0}^{N} f_{n+1} \left(C_{k,n} S_{k,1} + S_{k,n} C_{k,1}\right) \tag{30}$$

$$= \sum_{n=0}^{N} f_{n+1} \; S_{k,n+1}$$

$$= b_k - f_o \; S_{ko} + f_{n+1} \; S_{k,n+1}$$

From Equation 28,

$$\begin{array}{ll} C_{k,0} = 1 & C_{k,n+1} = C_1 \\ S_{k,0} = 0 & S_{k,n+1} = S_1 \end{array} \tag{31}$$

Substituting Equations 31 into Equations 30,

$$\begin{array}{l} a_k'C_{k,1} - b_k'S_{k,1} = a_k - f_o + f_{n+1} \; C_{k,1} \\ a_k'S_{k,1} + b_k'C_{k,1} = b_k + f_{n+1} \; S_{k,1} \end{array} \tag{32}$$

Solving for a_k' and b_k' simultaneously,

$$\begin{array}{l} a_k' = C_{k,1} \left(a_k - f_o + f_{n+1} \; C_{k,1}\right) + S_{K,1} \left(b_{k,1} + f_{n+1} \; S_{k,1}\right) \\ b_k' = S_{K,1} \left(a_k - f_o + f_{n+1} \; C_{k,1}\right) + C_{k,1} \left(b_{k,1} + f_{n+1} \; S_{k,1}\right) \end{array} \tag{33}$$

In Equation 33, the coefficients a_k' and b_k' are expressed recursively in terms of the first and next values of $f(t)$ in the Fourier interval, the immediately pre-ceeding coefficients, and the cosine and sine of that frequency for n=1. By graphing the coefficients or the magnitude of the two for a k value, one can observe the trend for that frequency.

3.2 FOURIER FILTER OPERATION

The Fortran 77 listing in Appendix C is implemented on a Hewlett Packard 9000. Although we run the filter in series with our digital single precision simulation, it is designed to accept data in parallel as a subroutine might. There is a descriptive list of variables at the beginning of the computer program.

From Equation 26 we define the frequency interval as the fundamental frequency (k=1) of the input function, f(t):

$$\omega_0 = \frac{2\pi}{\tau} \equiv \Delta\omega \tag{34}$$

For a sampling of N simulation points each separated by the simulation time step DT,

$$\tau = N \cdot DT$$

$$\Delta\omega = \frac{2\pi}{N \cdot DT} \tag{35}$$

The user selects a frequency interval (FREINT) and inputs the simulation DT. N is calculated from Equation 35 to insure that the user's choice of filter frequency (FILFRE) will be an integral multiple of $\Delta\omega$. Because N is an integer and it is essential that f_0 is exactly N + 1 points from f_{n+1}, $\Delta\omega$ is recalculated within the program using Equation 35.

The wave number, k' that will give FILFRE (ω) is

$$k' = \frac{\omega}{\Delta\omega} \tag{36}$$

Up to 4 other frequencies are chosen on each side of k' to give a frequency band.

The program uses either simulation time, number of sampled points, or number of Fourier intervals to signal termination. The program will stop when it reaches the first of these conditions. In our program we control resolution of graphics output by changing NPTPLT, the number of points per plot.

Output variable, AK, BK and RMAG are sent to a file in a format acceptable to our plot programs. We have found that RMAG plots are the most easily analyzed for the high freqencies we are interested in. RMAG for several frequencies can be sent to the analog parts of the hybrid for output to strip chart recorders. The result is a real time frequency filter that can indicate dominant frequencies while the program is running without having to wait for transient simulation variables to settle out. The filter frequency can be adjusted during a run-time input.

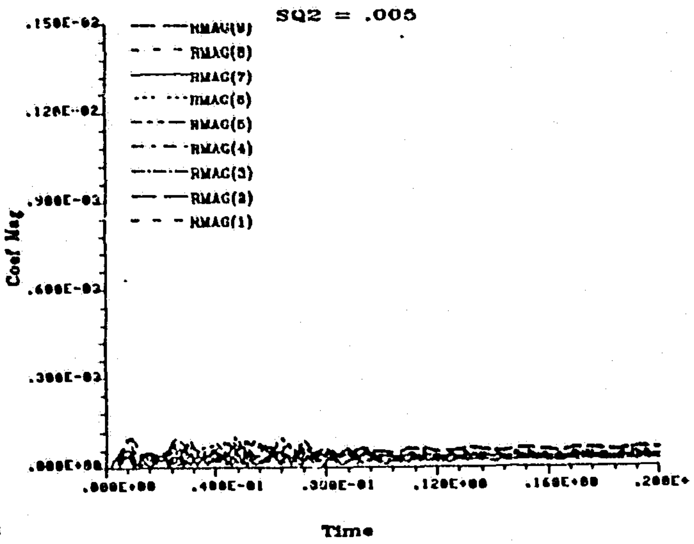
The program filters nine frequency values; the highest coefficient magnitudes on the plots belong to those frequencies closest to the unstable frequency. In this example the simulation on the PDP was run with SQ2 = .005. Figures 7 through 10 graphically represent filter output at the Preburner Pump End Bearings. When the filter frequency is set at 3400 rad/sec with a frequency interval of 100 rad/sec, coefficients of frequencies from 3000 to 3800 rad/sec are plotted. The largest coefficients occured at 3800 rad/sec with little slope, indicating that the unstable whirl frequency is outside this range (Figure 7).

When the filter frequency is set to 4300 rad/sec the coefficients at 4200 rad/sec (RMAG(4) have the greatest magnitude (Figure 8). Successive runs with frequency intervals set to 50 and 25 rad/sec (Figures 9 and 10) limits the unstable frequency possibilities to between 4162 and 4188 rad/sec. The effects of displacement along the rotor axis can be seen by comparing Figures 10, 11, and 12. It is possible to derive the relative mode shapes in this manner.

The frequency interval, $\Delta\omega$, and number of points required for a Fourier interval are inversely related; a decrease in $\Delta\omega$ requires a larger number of points, N, and a greater sampling time, τ, before acceptable data is available. The time step between sampled points can be increased, to reduce the number of points sampled and therefore the number of data points kept in an array. However, a greater sampling time must still be used.

For example, in Figure 9 the number of points in the Fourier interval is 4117, and the frequency interval is 50 rad/sec. The data is good after .127 seconds. When the frequency interval is reduced to 25 rad/sec, the Fourier interval is maintained at 4117 by taking every other displacement point from the simulation, i.e. $DT \approx 6.104 \times 10^{-5}$. It is clear from Figure 10 that the data is acceptable after .25 seconds. Although we have actually increased the amount of simulation time necessary to filter frequency to a resolution of 25 rad/sec, the number of data points in our array is maintained to prevent twice the number of calculations. We have taken up to every tenth simulation point with no observable differences in graphs. This is not necessarily a limit; but because it would require a very long simulation run, we stopped there.

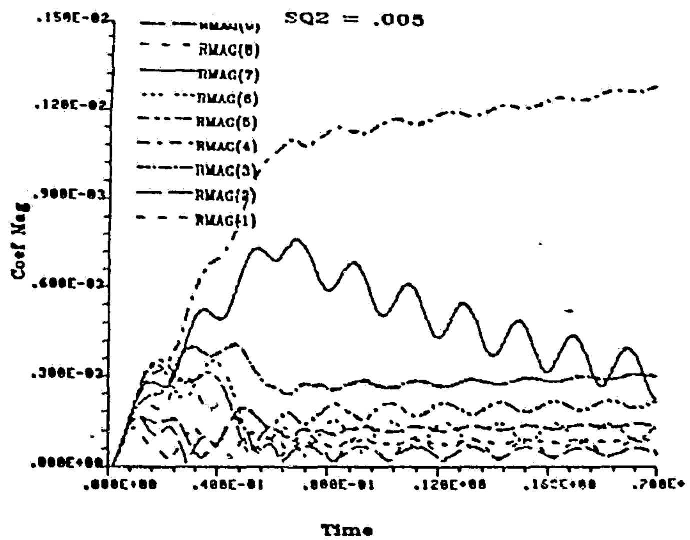
FIGURE 7



NN : 2059
DT : 3.052200E-05
FILTER FREQUENCY : 3.400000E+03
FREQUENCY INTERVAL : 9.997941E+01
DATA GOOD AT T= 6.446280E-02
JOINT NUMBER : 6 (PREBURNER PUMP SEALS)

FCN	K	OMEGAK
1	30	2999.382
2	31	3099.362
3	32	3199.341
4	33	3299.321
5	34	3399.300
6	35	3499.279
7	36	3599.259
8	37	3699.238
9	38	3799.218

FIGURE 8



NN : 2059
DT : 3.052200E-05
FILTER FREQUENCY : 4.300000E+03
FREQUENCY INTERVAL : 9.997941E+01
DATA GOOD AT T= 6.446280E-02
JOINT NUMBER : 6 (PREBURNER PUMP SEALS)

FCN	K	OMEGAK
1	39	3899.197
2	40	3999.176
3	41	4099.156
4	42	4199.135
5	43	4299.115
6	44	4399.094
7	45	4499.073
8	46	4599.053
9	47	4699.032

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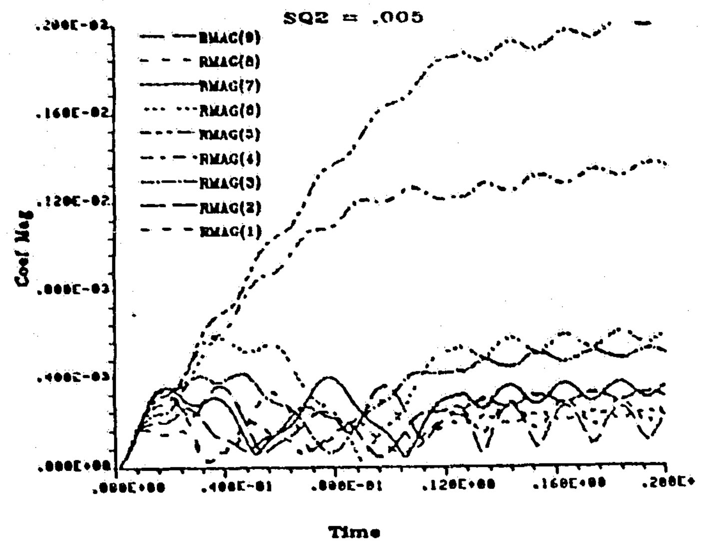
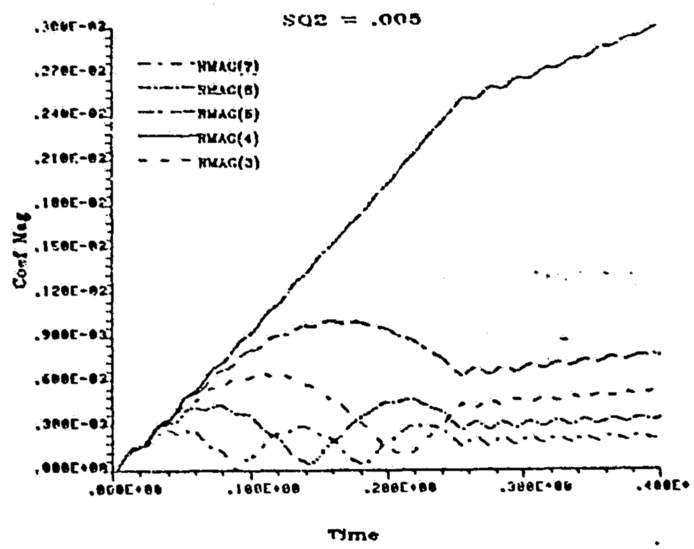
FIGURE 9



NN : 4117
DT : 3.052200E-05
FILTER FREQUENCY : 4.200000E+03
FREQUENCY INTERVAL : 5.000185E+01
DATA GOOD AT T= 1.272771E-01
JOINT NUMBER : 6 (PREBURNER PUMP SEALS)

FCN	K	OMEGAK
1	80	4000.148
2	81	4050.150
3	82	4100.152
4	83	4150.153
5	84	4200.155
6	85	4250.157
7	86	4300.159
8	87	4350.161
9	88	4400.163

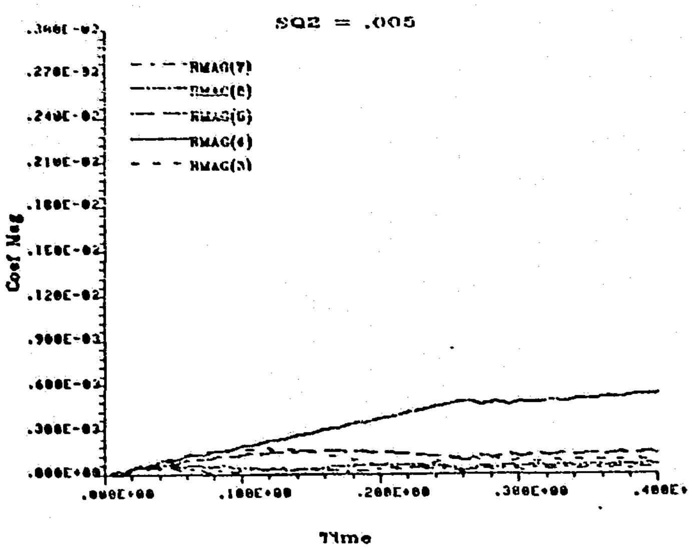
FIGURE 10



NN : 4117
DT : 6.104400E-05
FILTER FREQUENCY : 4.200000E+03
FREQUENCY INTERVAL : 2.500093E+01
DATA GOOD AT T= 2.545531E-01
JOINT NUMBER : 6 (PREBURNER PUMP SEALS)

FCN	K	OMEGAK
1	164	4100.152
2	165	4125.153
3	166	4150.153
4	167	4175.154
5	168	4200.155
6	169	4225.156
7	170	4250.157
8	171	4275.158
9	172	4300.159

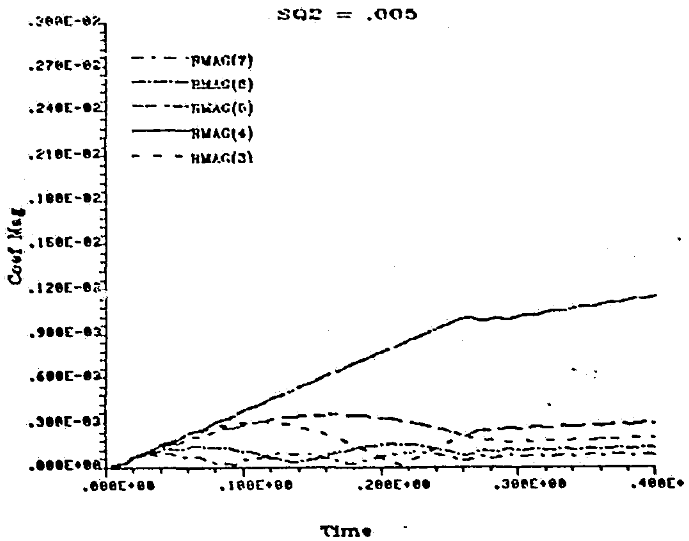
FIGURE 11



NN : 4117
DT : 6.104400E-05
FILTER FREQUENCY : 4.200000E+03
FREQUENCY INTERVAL : 2.500093E+01
DATA GOOD AT T= 2.545531E-01
JOINT NUMBER : 2 (TURBINE END BEARINGS)

FCN	K	OMEGAK
1	164	4100.152
2	165	4125.153
3	166	4150.153
4	167	4175.154
5	168	4200.155
6	169	4225.156
7	170	4250.157
8	171	4275.158
9	172	4300.159

FIGURE 12



NN : 4117
DT : 6.104400E-05
FILTER FREQUENCY : 4.200000E+03
FREQUENCY INTERVAL : 2.500093E+01
DATA GOOD AT T= 2.545531E-01
JOINT NUMBER : 3 (BALANCE PISTON)

FCN	K	OMEGAK
1	164	4100.152
2	165	4125.153
3	166	4150.153
4	167	4175.154
5	168	4200.155
6	169	4225.156
7	170	4250.157
8	171	4275.158
9	172	4300.159

The analysis of filter output is illustrated in Figures 13 and 14. These plots are output from a test case where a simple sinusoidal function, $F(t) = \exp(.005t)\sin(.63t) + \exp(-.002t)\sin(.88t)$ was input to the filter. The peaks are measured on the AK coefficient graphs and alpha computed using the same methods as used for hybrid simulation displacements. The dominant growth rate with the filter set at at .628 rad/sec is indeed .005. The growth rate can also be accurately derived from the magnitude plots by using the relationship derived here.

$$Mag_0 = Ke^{\alpha t_0} \quad \text{at } t_0 \text{ (first point in sampling period)} \tag{37}$$

$$Mag = Ke^{[\alpha(t_0 + \Delta t)]} \tag{38}$$

$$\frac{Mag}{Mag_0} = e^{\alpha \Delta t} \tag{39}$$

$$\alpha = \frac{\ln \dfrac{Mag}{Mag_0}}{\Delta t} \tag{40}$$

According to Figure 13 the output is not good until after 100 seconds. Picking a peak after 100 seconds on Figure 14a we measure its peak to peak amplitude (1) and that of another peak (2). By choosing n=1 in Equation 12, Sec. 2.1, one can get many readings to eliminate possible error due to time step choice or poor plotting resolution. In this case,

$$\alpha = \frac{.628 \ln \dfrac{412}{393}}{\sqrt{4\pi^2 - \left(\ln \dfrac{412}{393}\right)^2}} \tag{41}$$

(Lengths are measured in .01 inch increments). .63 is the filter frequency which can be checked by reading number of cycles per unit time off graph and converting to radians.

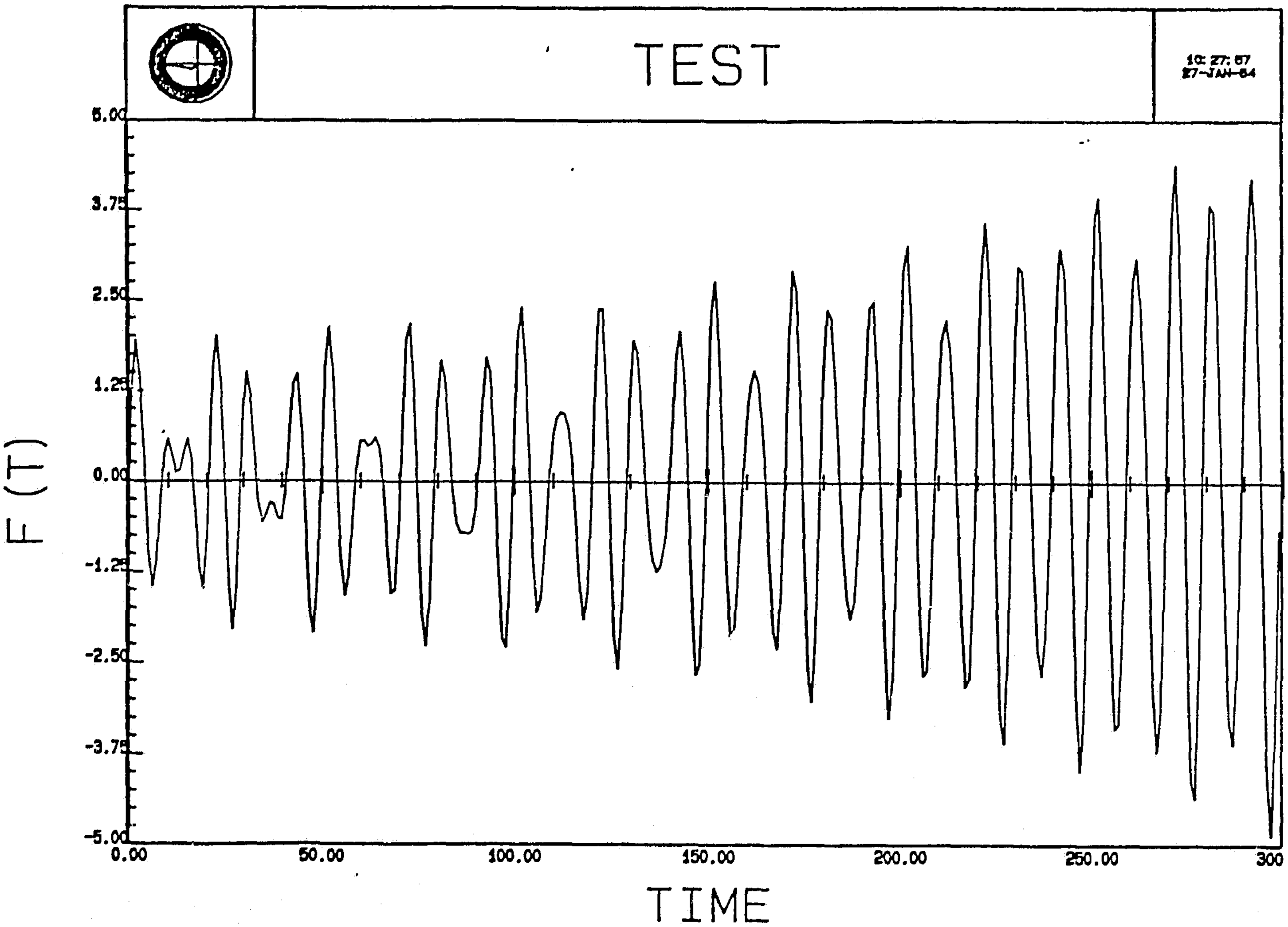


FIGURE 13 FOURIER FILTER INPUT

$F(T) = e^{.005T}\sin(.63T) + e^{-.002T}\sin(.88T)$

NN (no. of points in sampling period) = 100

DT = 1.0 sec

Filter Frequency = .63

Frequency Interval = 6.28×10^{-2}

For k = 10, OMEGAK = .628

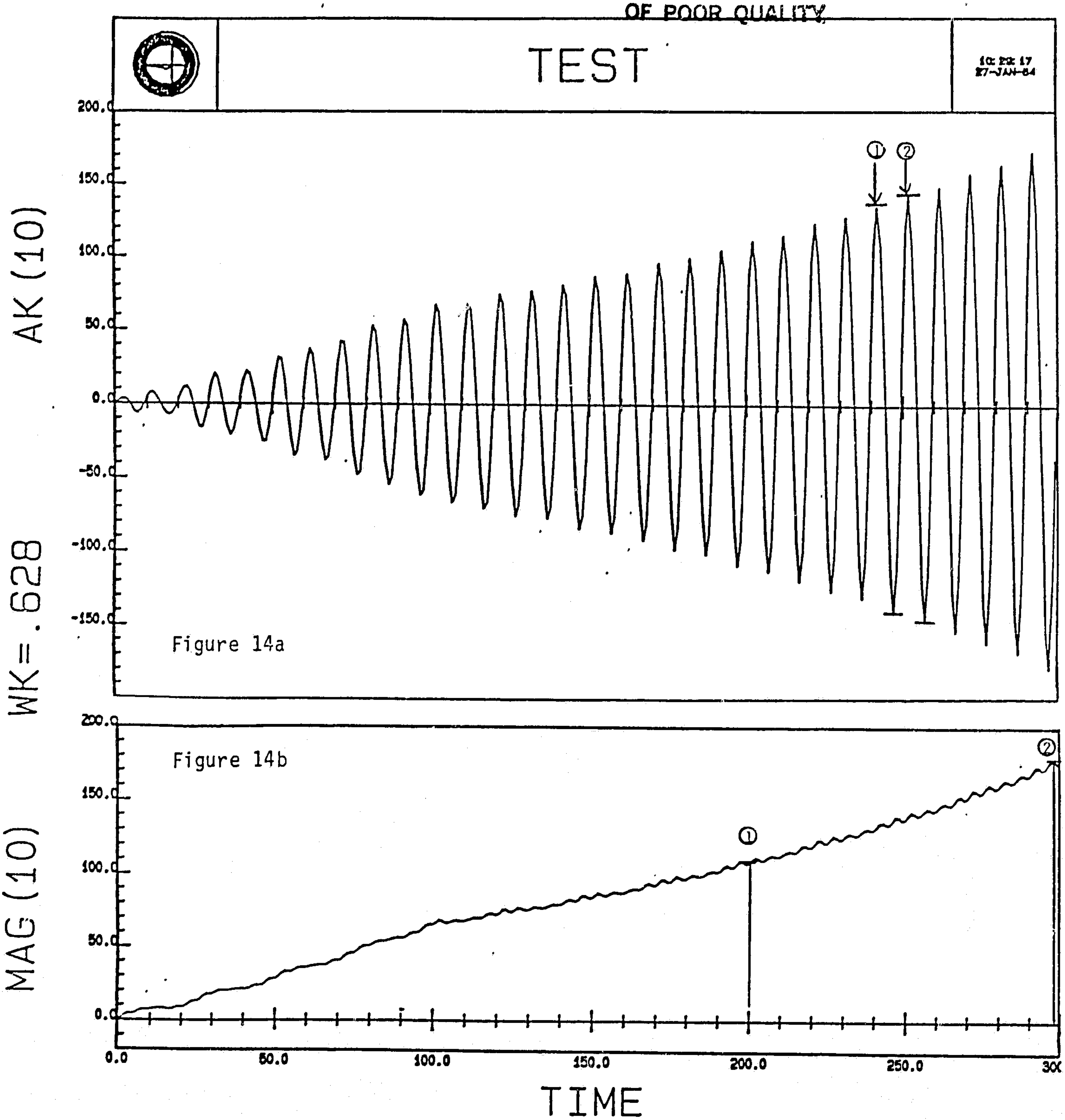


FIGURE 14 FOURIER FILTER OUTPUT

Using Equation 29 and Figure 14b we get the same results by measuring from 0 to same point in cycle for several places along curve. Using points 1 and 2,

$$\alpha = \frac{\ln \dfrac{252}{153.5}}{100} = .005 \; . \tag{42}$$

4.0 SUMMARY

Under this study we discovered some minor errors, none of which are expected to cause significant changes in predicted bearing loads or responses, although they do cause the stability boundary to shift upward. For this reason, the sign of the GAMO terms should be corrected on the production version as soon as possible. Although not as significant as the apparent sign error of GAMO, the other errors discovered need to be changed to assure the accuracy of the hybrid model and its agreement with the stability model. These include dropping those terms in the equations of motion multiplied by the rotor rotational acceleration, declaring the Alford seal stiffness coefficient (KSA) real, and including the relative displacement DPP when multiplying the deadband stiffness coefficients.

We found that for reading whirl frequencies from the strip chart recorder, an error of 1000 to 2000 RPM, at a strip chart recorder setting of 5 volts/line is possible. However, using lower volts/line setting to enlarge recorder output, meticulous reading of charts, and averaging several readings can be used to minimize errors. With these techniques, errors of 240 to 400 RPM when recorder is set to 2 volts/line are achievable.

There are some inconsistent hybrid simulation results that we were unable to irrefutably attribute to any one source. The primary example being the SQ3 cases presented in Section 2.5. We were unable to determine why recordings of ± PHIDX In December were unsymmetrical, while those run in February react as expected. There have been other instances where identical input did not produce identical output. Our attempts to characterize these inconsistencies did not demonstrate anything conclusive, although there are indications that hardware malfunctions and/or hysteresis are the causes.

The Fourier Filter algorithm we have developed would be a valuable enhancement to the simulation, allowing for real time frequency analysis. The filter uses a recursive Fourier series algorithm to analyze displacement amplitudes at different frequencies. Several frequencies could be evaluated with the results for each going to a different strip chart recorder channel for analysis.

CONCLUSION

The primary concern of this study has been to define and quantify any problems in the SSME hybrid turbopump simulation model. This has been done by a review of the derivation of the system equations of motion and by a painstaking comparison between a linearized stability model and the nonlinear hybrid model where both have been set up with the same data and conditions. We have made our recommendations of corrections for the four errors we have discovered and we feel these corrections will remove the remaining differences between the hybrid and the stability models. The problems we have discovered do not invalidate the results run in the past but the corrections we have recommended should result in closer agreement between the linear and hybrid, nonlinear models. From our comparisons between simulation results, we can say that, with all recommended corrections made, the SSME hybrid turbopump simulation correctly models the equations of motions, including the known whirl drivers and significant nonlinearities with sufficient accuracy.

REFERENCES

"Analysis of SSME HPTOP Rotordynamics Subsynchronous Whirl", Final Report, NASA Contract NAS8-34924, Control Dynamics Company, October 1982.

```
C     LOXI11-6-77
C     LOXI11-7-77                                                    2
C     LOXI11-11                                                      3
C     F(9) FLEX MODIFIED 1176/77
C     F(15) FLEX... MODIFIED ON 1/20/78
C     F(16) FLEX... MODIFIED ON 2/2/78
C     F(17) FLEX... MODIFIED ON 2/27/78
C     F(18) FLEX... MODIFIED ON 3/31/78
C     F(19) FLEX... MODIFIED ON 3/31/78
C     F(21) FLEX... MODIFIED ON 7/12/78
C     F(22) FLEQ... MODIFIED ON 8/9/78
C     F(23) FLEX... MODIFIED ON 1/20/79
C     F(24) FLEX... MODIFIED ON 2/16/79
C     F(25) FLEX... MODIFIED ON 6/23/79
C     F(27) FLEX... COMPILED ON 3/21/80
C     F(28) FLEX... COMPILED ON 3/21/80
C     F(29) FLEX... COMPILED ON 10/32/80
C
C
      COMMON/DATAJB/CL,C1,C2,C3,ELOD3,PI2,KMAX                       30
      COMMON/T/T,DT,TF,CT02,DT204
      COMMON /BENDIN/ PHIR(3,20,1),FTER(3,20,1),PHIC(3,24,10),PSICBX(10)
     *,FEEC(3,24,10),MOCC,IRP,IRT,IRI,IRB,IRS1,IRS2,IRS3,ICB,ICA,ICP,ICT
     *,ICS1,ICS2,ICS3,PHICBX(10),PHIMBY(10),PHICBZ(10),PSICAX(10)
     *,PHICPY(10),PHICPZ(10),PHICTY(20),PHICTZ(10),PHICAY(10),RHICAZ(10)
     *,PHICS1Y(10),PHICS1Z(10),PHICS3Y(10),PHICS2Z(10),PHICS3Y(10)
     *,PHICS3Z(10),PHIRF,PHIRT,PHIRAEPHIRB,PHIRS1,PHIRS2,PHIR83
     *,AC1(10),AC2(10),AC3(10),AC4(11),AC5(10),AC6(10),AC7(10)
     *,CAC1(3),CAC2(3),CAC3(3),CAC4(4),CAC5(3),CAC6(3),CAC7(3)
     *,DAC1(3),DAC2(3),DAC3(3),DAC4(4),DAC5(3),DAC6(3),DAC7(3)
     *,JAC1,JAC2,JAC3,JAC4,JAC5,JAC6EJAC7
     *,OHMC(10),R(20),AMR(13),AIR1(16),AIR2(16),AIR3(15),OHMR,OHMRSB
      COMMON /CELTIN/ DELPY,DELPZ,DEUTY,DELTZ,DELAY,DELAZ,DELBX,DELS1Y
     * ,DELS2Y,DELS3Y,DELS1Z,DELS2Z,LELS3Z,DELP,DELT,DELA,OMIN,DELDPY
     * ,DELDPZ,DELDTY,DELDTZ,DELDBX,LELDAY,DELDAZ,DELDS1Y,DELDS2Y
     * ,DELDS3Y,DELDS1Z,DELDS2Z,DELDS3Z, X,Y,Z,XD,YD,ZD,LP,LT,LA,LS1
     * ,LS2,LS3,PHIZ,PHIY,PHIDZ,PHIDP,XIY,XIZ,XIDY,XIDZ,ETA(10),ETAD(10)
     * ,VHF,OPP,OP,UP,DELPPY,DELPPZ,CPP,DPPPY,DPPPZ,DELDPPY,DELDPRZ
     * ,DDPPPY,DDPPPZ,VKT,OPT,OT,UT,LELPTY,DEL2TZ,UPT,DPPTY,DPPTZ
     * ,DELDPTY,DELDPTZ,DDPPTY,DDPPTV
C
      DIMENSION ZERO(32)                                             6
      DIMENSION DAI(32),SFI(32)
      DIMENSION IBIAS(64)
      DIMENSION OHMCSC(10)
      DIMENSION TIME(10),SPEED(10)
      DIMENSION ETADD(10)
      DIMENSION ETADDE(10),ETADB(10)EETAB(10)                        12
      DIMENSION ETADDBB(10),ETADBB(11),ETABB(10)                     13
      DIMENSION TWOZETC(10)                                          18
      DIMENSION DAIMAX(32),DAIMIN(32<
      DIMENSION DAIMXAVG(32),DAIMNAVB(32)
      DIMENSION ICARD(5,64),XSCALE(65),DAC(64),SCALE(64),ICHNNL(32)
```

```
      DIMENSION TPH(DX(10),SLY(10),SUZ(10),SLB1Y(1C),SLS1Z(10),SLB2Y(10)    26
      DIMENSION SLS2Z(1C),SLS3Y(10),DLS3Z(10),SLAY(10),SLAZ(10)             27
      DIMENSION BUFFRA(10,128),BUFFRB(10,128),IOUT(10),AOUT(10),TDUMP(B)    29
      DIMENSION APUMP(3)
C                                                                           28
C** ******************************************************************      31
      LOGICAL ITAPE                                                         32
      LOGICAL ICARDS,IWAIT,IBACK                                            33
      LOGICAL IREMOD
      LOGICAL ITOF
      LOGICAL IGATHER
      INTEGER SLGATHER
      INTEGER SLRMOD
      INTEGER SLTOF
      INTEGER SLWAIT,SLCARD,SLBACK                                          34
      INTEGER AOLT                                                          35
C                                                                           36
      DATA KVWPT/0/
      REAL LS3,KS3, KSA                                                     37,
      REAL LR(20)                                                           38
      REAL LP,LT,LA,LS1,LS2,KPY,KPZ,JTY,KTZ,KS1,KS2,KB                      39
      REAL LB                                                               40
      REAL M,I2,I1                                                          41
      REAL KPPY,KPPZ,KPTY,KPTZ                                              42
      REAL MTWP1                                                            43
      LOGICAL IEXIT                                                         44
C** ******************************************************************      45
C** ******************************************************************      46
C                                                                           47
      DATA SLGATHER/12/
      DATA SLRMOD/11/
      DATA SLTOF/10/
      DATA SLWAIT,SLCARD,SLBACK/5,6,8/                                      48
      DATA IIDUMP/1/                                                        49
      DATA IIPULS/1/                                                        50
      DATA INORD/0/                                                         51
      DATA XMUN/0/                                                          52
      DATA XIDC/1./                                                         53
      DATA AOUT/10*4HNULL/,MTAPE/5/,SSLTAP/2/,ITYPE/102/,LPR/108/           54
      DATA NMAX/8192/,IMAX/128/,NCHAN/10/,IOUT/10*1/                        55
      DATA BUFFRA/1280*0.,/BUFFRB/1280*0./,TDUMP/5*20./                     56
      DATA KCHAN/0/                                                         57
      DATA R/20*0./                                                         60
      DATA PHIR,FEER/120*0./                                                62
      DATA FEEC,PHIC/1440*0./                                               63
      DATA OHMC/0./                                                         64
C     SEVERAL INDICES NEED TO BE SET TO DIFFERENTIATE BETWEEN LOX PUMP
C     AND FUEL PUMP BENCING MODES...
C     IE, ICP,ICT,ICB,ICA,ICS1,ICS2,SCS3,IRP,IRT,IRB,IRA,IRS1,IRS2,IRS3
C     ALSO INDICES JAC1,JAC2,...,JAC8, AND BETA, CAC1( ),DAC( ),...ETC.
      DATA CAC1,CAC2,CAC3,CAC4,CAC5,BAC6,CAC7/21*0./   ?
      DATA DAC1,DAC2,DAC3,DAC4,DAC5,LAC6,DAC7/21*0./   ?
C
```

```
C     THIS SEAL IS NOT IN FUEL PUMP, HENCE...
      DATA PHICS3Y/10.0/,PHICS3Z/10.0/,PHIRS3/0./
      DATA LS3/0/
C
      DATA AKPY0,AKPY1,AKPY2,AKPY3/4*0./                                68
      DATA AKPZ0,AKPZ1,AKPZ2,AKPZ3/4*0./                                69
      DATA AKTY0,AKTY1,AKTY2,AKTY3/4*0./                                70
      DATA AKTZ0,AKTZ1,AKTZ2,AKTZ3/4*0./                                71
      DATA CPPY,CPPZ,CPTY,CPTZ/4*0./                                    72
      DATA SLZ,SLY,SLS1Y,SLS1Z,SLS2Y,SLS2Z,SLS3Y,SLS3Z,SLAY,SLAZ/100*0./ 73
      DATA SKA0,SKA1,SKA2,SQA0,SQA1,SQA2,SCA0,SCA1,SCA2/9*0./
      DATA SK10,SK11,SK12,SQ10,SQ11,SQ12,SC10,SC11,SC12/9*0./
      DATA SK20,SK21,SK22,SQ20,SQ21,SQ22,SC20,SC21,SC22/9*0./
      DATA SK30,SK31,SK32,SQ30,SQ31,SQ32,SC30,SC31,SC32/9*0./
      DATA TWOZETR/.01/                                                 75
      DATA TWOPI/6.28318/                                               76
      DATA MTWPI/-6.28318/                                              77
      DATA IPULSE/1/                                                    79
      DATA DMIN/1.E-15/                                                 80
      DATA ZERO/32*0./                                                  81
      DATA SF1/32*1./                                                   82
      DATA IBSEPBC/0/
      DATA              BKPY,BKPZ,BKTY,BKTZ/4*1./
      DATA XSCALE/64*0./
      DATA DAC /64*0./
      DATA SCALE/64*1./
      DATA ICHNNL /1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,
     *21,22,23,24,25,26,27,28,29,30,31,32/
      DATA OSPEED/1./                                                   85
      DATA DES1Y,DES1Z/2*0./                                            86
      DATA FSIMAX/1.E6/                                                 87
      DATA ICAV/2/                                                      88
      DATA RP,RT,ELP,ELT,UMP,UMT/6*0./                                  89
      DATA FSFPY,FSFPZ,FSFTY,FSFTZ/4*0./                                90
      DATA DT2M15/.30517578125E-4/
      DATA XSLBH/1./
      DATA EMAXP,EMAXT/2*0./                                            91
      DATA AKPY4,AKPZ4,AKTY4,AKTZ4/4*1./
      DATA ISICEL/0/
      DATA SLK,SLS1K,SLS2K,SLS3K,SLAK/5*1./
      DATA THSLOS,THSL,THSLS1,THSLS2,THSLS3,THSLA/6*0./
      DATA TIMIST/.0625/,CCRTST/8192./
      DATA IDCTST/-1/
      DATA NUMLINESPP/10/
      DATA APUMP/4HNULL,4HHPFT,4HHPOA/
      DATA KPY,KPZ,KTY,KTZ,KPPY,KPPZ,KPTY,KPTZ/8*0./
      DATA FCAPPY,FCAPPZ,FCAPTY,FCAPTZ/4*0./
      DATA KPUMP/1/
C
C
C     ***************************************************************
C
C       IMBALANCE POSITIONS
```

ORIGINAL PAGE IS OF POOR QUALITY

```
C
C     MAIN IMPELLER=BALANCE PISTON=CMB.
C     TURBINE=ALFORD FORCE=UMA.
C     PRE-BURNER PUMP=SEAL 2=UM2.
C
C     ************************************************************
C
C
      NAME LIST                                                         92
C
      CALL WDAC(C,32,ZERO,SF1)
C
C     FILE 115 CONTAINS MAINLY CHANNEL SCALING AND OUTPUT DATA
      INPUT(115)                                                        93
C
C
C
C     ICHNNL(I)= INDEX (IN DAC) WHICH IS TO BE OUTPUT ON THE ITH DAC
C     IE, CONSIDER)
C     THE VALUE OF TRUNK 407 IS DETERMINED BY DA1(7) AND SF1(7)
C
C     IF ICHNNL(7)=I, THEN DA1(7) = DAC(I) AND SF1(7) = SCALE(I).
C     FURTHERMORE, XSCALE(I) AND ICIRD(1-5,I) DESCRIBE THIS CHANNEL.
C
C**  ***********************************************************        94
C     MOD TO OUTPUT RECORDER 8 ASSIGNMENTS                              95
C                                                                       96
      DO 802 J=1,64
  8 2 READ(115,71,END=75) (ICARD(I,J),I=1,5),XSCALE(J),IBIAS(J)
    5 CONTINUE
    1 FORMAT(5(A4),F8.2,15X,I4)
      WSEMOD=C
 2C 1 CONTINUE
      WRITE(108,757)                                                    99
  7 7 FORMAT(1H1)                                                      100
      WRITE(ITYPE,755)                                                 101
  7 5 FORMAT(' INPUT RUN-ID (A4)')                                     102
      READ(ITYPE,754)RUNID                                             103
  7 4 FORMAT(A4)                                                       104
      WRITE(108,2666) APUMP(KPUMP),RCNID
 26 6 FORMAT(/1X,46(1H*),1X,A4,'P RUN IDENTIFICATION ',A4,1X,50(1H*)//)
      WRITE(1C8,72)                                                    107
    2 FORMAT(//8X,'CHANNEL ASSIGNMENTS',13X,'FULL SCALE (100 VOLTS) =',  108
     *25X,'NOMINAL SCALE (PER LINE)'/93X,'VOLTS',8X,'UNITS'//)        109
      DO 74 K=1,32                                                     110
      J=ICHNNL(K)
      SF1(K)=SCALE(J)
      XF1=SF1(K)*XSCALE(J)*C1
      WRITE(1C8,73)K,(ICARD(I,J),I=1,3),SF1(K),(ICARD(I,J),I=4,5),
     *XSCALE(J),XF1,(ICARD(I,J),I=4,5)
    4 CONTINUE                                                         114
    3 FORMAT(1CX,I2,2X,3A4,16X,E12.5,1X,2A4,30X,F8.2,3X,E12.5,1X,2A4)  115
      REWIND 115                                                       117
```

A4

```
      WRITE(108,787)                                                   118
      IF(JREMOD.EQ.1)GO TO 2002
      PI2=1.570796327                                                  119
      M= 0.0                                                           120
      CM= 0.0                                                          121
      GAM0= 0.0                                                        122
      GAM1= 0.0                                                        123
      I1= 0.0                                                          124
      I2= 0.0                                                          125
      NUMRUN = 1
      IGATHER = .FALSE.
      KGPASS=0
      MAXGPASS=1024
C
      CALL BENDING
C
      DO 1006 J= 1,JNTR                                                163
      M=M+AMR(J)                                                       164
      CM= CM+AMR(J)*R(J)                                               165
 1006 CONTINUE                                                         166
      CM= CM/M                                                         167
      DO 1004 J=1,JNTR                                                 168
      LR(J)= R(J)-CM                                                   169
      I1= I1+AIR1(J)                                                   170
      I2= I2+AMR(J)*LR(J)*LR(J)+AIR2(J)                                171
      GAM0= GAM0+AIR1(J)*PHIR(3,J,1)                                   172
      GAM1= GAM1+AIR1(J)*PHIR(3,J,1)*PHIR(3,J,1)                       173
 1004 CONTINUE                                                         174
      LP= LR(IRP)                                                      175
      LT= LR(IRT)                                                      176
      LA= LR(IRA)                                                      177
      LB= LR(IRB)                                                      178
      LS1= LR(IRS1)                                                    179
      LS2= LR(IRS2)                                                    180
C
C     THIS SEAL IS NOT IN FUEL PUMP, HENCE...
      IF (IRS3.GT.0) LS3=LR(IRS3)
C
C                                                                      182
      IMAX10=IMAX+10                                                   183
      KDUMP=0                                                          184
      KTAPE=0                                                          185
      ICUMP=1                                                          186
C     FILE 116 CONTAINS ALL MODIFICAAION DATA
      INPUT(116)
      REWIND 116
C
 2002 CONTINUE
C                                                                      187
C     ***********************************************************
C
C      INPUT BLOCK FOR TAPE GENERATINN                                 189
C
```

```
C      KCHAN IS NUMBER OF VALID CHANNELS OF OUTPUTTED DATA                  188
C      KCHAN HAS MAXIMUM VALUE OF 9
C      IOUT(1) IS NOT USED...
C      IOUT(K) IS THE INDEX (IN ICHNNL) OF THE KTH DAC TO BE SENT TO TAPE
C
       TIMEON=20.                                                          191
       WRITE(ITYPE,708)                                                    192
   708 FORMAT(' INPUT NUMBER OF CHANNELS (I1) : ')                         193
       READ(ITYPE,709)KCHAN                                                194
   709 FORMAT(I1)                                                          195
       IF (KCHAN.EQ.0)GO TO 711                                            196
       AOUT(1)=4HTIME                                                      197
       DO 712  J=1,KCHAN                                                   198
       K=J+1                                                               199
       L=IOUT(K)
       I=ICHNNL(L)
       AOUT(K)=ICARD(1,I)                                                  201
   712 CONTINUE                                                            202
       TIMEON=TOUPP(I)                                                     203
   711 CONTINUE                                                            204
C
C      ************************************************************************
C                                                                          205
       CALL RSL(ICARDS,$LCARD)                                             206
       IF(ICARDS)GO TO 1100                                                207
       WRITE(ITYPE,1101)                                                   208
  1101 FORMAT(' INPUT (I1) FOR UPDATE FILE')
       IFILE=0                                                             210
       READ(ITYPE,1102)IFILE                                               211
  1102 FORMAT(I1)                                                          212
       IF(IFILE.EQ.0) GO TO 1100                                           213
       IFILE=IFILE+300                                                     214
       INPUT(IFILE)                                                        215
       REWIND IFILE
  1100 WRITE(ITYPE,760)                                                    216
   760 FORMAT(' INPUT DATA MODS')                                          217
       INPUT(101)                                                          220
       XSLOW=0.
C      IN ORDER TO MODIFY THE DT CHANGE XSLOW...
C      XSLOW = 1.    DT=2**(-15)    NOMINAL
C      XSLOW =  .5   DT=2**(-16)
C      XSLOW =  .25  DT=2**(-17)    ... ETC.
       DT=DT2M15*XSLOW
       DT02=DT/2.                                                          221
       TWODT=DT+DT                                                         222
       DT2O4=DT02*DT02                                                     223
       C1P=2.*UPP*ELP*(RP/(GPP*GP))**4                                     224
       C1T=2.*UCT*ELT*(RT/(GPT*GT))**4                                     225
       C3P=ELP/2./RP                                                       226
       C3T=ELT/2./RT                                                       227
       C2P=2.*C3P**2                                                       228
       C2T=2.*C3T**2                                                       229
       ELOD2P=C3P**2                                                       230
```

```
      ELOD2T=C3P**2                                                    231
      CLP=GPP*OP
      CLT=GPT*GT
      IF(ISIDEL.EQ.-1) SLK=0 ; SLB1K=0 ; SLB2K=0 ; SLB3K=0 ; SLAK=0
      IF(JREMOD.EQ.1)GO TO 2003
      DO 800 K=1,MODC                                                  232
      OHMC(K)=OHMC(K)*TWOPI                                            233
  800 OHMCSQ(K)=OHMC(K)*OHMC(K)                                        234
      OHMRSQ=OHMR*OHMR                                                 235
 2003 CONTINUE
C                                                                      236
C   OUTPUT RIGID AND FLEX DATA                                         237
C                                                                      238
C** ********************************************************           305
      OUTPUT M,CM,I1,I2,GAMO,GAM1                                      239
      OUTPUT AMR                                                       240
      OUTPUT IRP,IRT,IRA,IRB,IRS1,IRS2                                 241
      OUTPUT IRS3                                                      242
      OUTPUT ICP,ICT,ICA,ICB,ICS1,ICS2                                 243
      OUTPUT ICS3                                                      244
      OUTPUT ICL                                                       245
      OUTPUT JNTR,MODR,JNTC,MODC
      OUTPUT JAC1,CAC1,DAC1
      OUTPUT JAC2,CAC2,DAC2
      OUTPUT JAC3,CAC3,DAC3
      OUTPUT JAC4,CAC4,DAC4
      OUTPUT JAC5,CAC5,DAC5
      OUTPUT JAC6,CAC6,DAC6
      OUTPUT JAC7,CAC7,DAC7
      OUTPUT BETA                                                      247
      OUTPUT GAO,GA1,GA2,GA3
      OUTPUT GA4
      OUTPUT R,LR                                                      248
      OUTPUT LP,LT,LA,LB,LS1,LS2                                       249
      OUTPUT LS3,KS1,KS2,KS3                                           250
      OUTPUT IBSEPBC,BKPY,BKPZ,BKTY,KKTZ
      OUTPUT AKPY0,AKPY1,AKPY2,AKPY3,AKPY4
      OUTPUT AKPZ0,AKPZ1,AKPZ2,AKPZ3,AKPZ4
      OUTPUT AKTY0,AKTY1,AKTY2,AKTY3,AKTY4
      OUTPUT AKTZ0,AKTZ1,AKTZ2,AKTZ3,AKTZ4
      OUTPUT AKPPY,AKPPZ,AKPTY,AKPTZ                                   253
      OUTPUT PHIRP,PHIRT,PHIRA,PHIRB,PHIRS1,PHIRS2                     254
      OUTPUT PHIRS3                                                    255
      OUTPUT PHICAY,PHICAZ,PHICBY,PHICBZ                               256
      OUTPUT PHICBX,PSICAX,PHICPY,PHICPZ,PHICTY,PHICTZ,PHICAY,PHICAZ   257
      OUTPUT PHICS1Y,PHICS1Z,PHICS2Y,PHICS2Z                           258
      OUTPUT PHICS3Y,PHICS3Z                                           259
      OUTPUT AC1,AC2,AC3,AC4,AC5,AC6,AC7                               260
      OUTPUT OHMR,OHMRSQ,OHMC,OHMCSQ                                   246
      OUTPUT OP,GT,GPP,GPT                                             261
      OUTPUT ICAV,RP,RT,UMP,UMT,ELP,TLT,EMAXP,EMAXT                    263
      OUTPUT C1P,C1T,C2P,C2T,C3P,C3T                                   264
      OUTPUT SKA0,SKA1,SKA2,SGA0,SGA1,SGA2,SCA0,SCA1,SCA2
```

```
      OUTPUT SK1C,SK11,SK12,SQ1C,SQ12,SQ12,SC10,SC11,SC12
      OUTPUT SK2C,SK21,SK22,SQ2C,SQ22,SQ22,SC20,SC21,SC22
      OUTPUT SK3C,SK31,SK32,SQ3C,SQ32,SQ32,SC30,SC31,SC32
      OUTPUT ES1MAX                                               266
      OUTPUT CPY,CPZ,CTY,CTZ                                      267
      OUTPUT CPPY,CPPZ,CPTY,CPTZ                                  268
      OUTPUT AKBC,AKB1,AKB2,ACBC,ACB2,ACB2                        269
      OUTPUT CPDBY,CPDBZ,CTDBY,CTDBZ                              270
      OUTPUT UMPY,UMPZ,UMTY,UMTZ                                  271
      OUTPUT UMBY,UMBZ,UMAY,UMAZ                                  272
      OUTPUT UM1Y,UM1Z,UM2Y,UM2Z                                  273
      OUTPUT UM3Y,UM3Z                                            274
      OUTPUT GSPEED                                               275
      OUTPUT IWBZETRA,IWBZETC                                     276
      OUTPUT XMUN,XIDC                                            277
      OUTPUT TIME,SPEED                                           278
      OUTPUT TIMEON,TDUMP,NMAX,IMAX,SMAXIO                        279
      OUTPUT DT,TF                                                280
      OUTPUT DT2M1B,XSLOW
      OUTPUT YDD,YD,Y,ZDD,ZD,Z                                    281
      OUTPUT PHIDDX,PHIDX,PHIX                                    282
      OUTPUT PHIDDY,PHIDY,PHIY                                    283
      OUTPUT PHIDDZ,PHIDZ,PHIZ                                    284
      OUTPUT XIDDY,XIDY,XIY,XIDDZ,XIDZ,XIZ                        285
      OUTPUT ETADD,ETAD,ETA                                       286
      OUTPUT SE1,SCALE,XSCALE,ICHNNL
      OUTPUT TPHIDX                                               288
      OUTPUT IDCTST,DCRTST,TIMTST
      OUTPUT ISIDEL
      OUTPUT THSLOS
      OUTPUT THSL,SLK,SLY,SLZ
      OUTPUT THSLA,SLAK,SLAY,SLAZ
      OUTPUT THSLS1,SLS1K,SLS1Y,SLS1V
      OUTPUT THSLS2,SLS2K,SLS2Y,SLS2V
      OUTPUT THSLS3,SLS3K,SLS3Y,SLS3V
      OUTPUT AKPDBY,AKPDBZ,AKTDBY,AKTDBZ                          290
      OUTPUT ABF                                                  292
      OUTPUT FCAPPY,FCAPPZ
      OUTPUT FCAPTY,FCAPTZ
      OUTPUT KPUMP
C** ******************************************************        291
      OUTPUT *                                                    306
C                                                                 307
      WRITE(181,757)                                              308
      WRITE(181,757)                                              309
      JREMOD=0
      CALL RSL(IREMOD,SLRMOD)
      IF(IREMOD)JREMOD=1
      IF(JREMOD.EQ.1)GO TO 2001
      CALL RSL(ITOE,SLTOE)
      IF(ITOE)WRITE(108,757)
C
C
```

```
C** ********************************************************
C
    1 CONTINUE
C
C
C     THIS SECTION PROVIDES THE ABILITY TO GATHER DATA DURING EXECUTION
C
      IF(IGATHER) GO TO 1401
      CALL RSL(IGATHER,SLGATHER)
      IF(.NOT. IGATHER) GO TO 1400
      DO 1402  I=1,32
      DAIMAX(I)=DAI(I)
      DAIMIN(I)=DAI(I)
 1402 CONTINUE
      CALL WDAC(0,32,ZERO,SF1)
 1401 CONTINUE
      KOPASS=KOPASS+1
      IF(KOPASS.GT.MAXOPASS)GO TO 1414
      DO 1403  I=1,32
      IF(DAIMAX(I).LT.DAI(I)) DAIMAX(I)=DAI(I)
      IF(DAIMIN(I).GT.DAI(I))DAIMIN(I)=DAI(I)
 1403 CONTINUE
 1400 CONTINUE
C
C
      CALL RSL(IREMOD,SLRMOD)
      IF(IREMOD)WRITE(ITYPE,1410)RUNSD, NUMRUN  /  GO TO 10
      GO TO 11
C
C     DATA WAS GATHERED THIS TIME
C
 1410 FORMAT(9H RUN=ID ,A4,1H. ,I2,12H JUST ENDED.)
 1411 FORMAT(19H GOT DATA. RUN=ID  ,A4,1H. ,I2,12H JUST ENDED.) ←
 1412 FORMAT(1H1,18H DATA FOR RUN=ID ,A4,1H. ,I2,2X,4HCHAN,3X,
     * 12H DESCRIPTOR ,3X,12H MAX. VALUE ,3X,12H MIN. VALUE,7X,F6.4,
     *  2H S)
 1413 FORMAT(25X,I2,4X,3A4,3X,E12.6,4X,E12.6)
 1414 CONTINUE
      WRITE(ITYPE,1411)RUNID,NUMRUN
      ELAPTIME=KOPASS*DT
      WRITE(IC8,1412)RUNID, NUMRUN,ELAPTIME
      DO 1405 K=1,32
      J=ICHNNL(K)
      WRITE(IC8,1413) K,(ICARD(I,J),S=1,3),DAIMAX(K),DAIMIN(K)
 1405 CONTINUE
      OUTPUT IPSEPBC,BKPY,BKPZ,BKTY,KKTZ
      OUTPUT AKPY0,AKPY1,AKPY2,AKPY3EAKPY4
      OUTPUT AKPZ0,AKPZ1,AKPZ2,AKPZ3EAKPZ4
      OUTPUT AKTY0,AKTY1,AKTY2,AKTY3EAKTY4
      OUTPUT AKTZ0,AKTZ1,AKTZ2,AKTZ3EAKTZ4
      OUTPUT KPY,KPZ,KTY,KTZ,KPPY,KPPZ,KPTY,KPTZ
      OUTPUT OHMS,OHMRSG
      OUTPUT GP,GT,GPF,GPT
```

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```
      OUTPUT ICAV,RP,RT,UMP,UMT,ELP,TLT,EMAXP,EMAXT
      OUTPUT C1P,C1T,C2P,C2T,C3P,C3T
      OUTPUT FS1MAX
      OUTPUT CPY,CPZ,CTY,CTZ
      OUTPUT CPPY,CPPZ,CPTY,CPTZ
      OUTPUT AKBO,AKB1,AKB2,ACBO,ACB2,ACB2
      OUTPUT CPDBY,CPDBZ,CTDBY,CTDBZ
      OUTPUT UMPY,UMPZ,UMTY,UMTZ
      OUTPUT UMBY,UMBZ,UMAY,UMAZ
      OUTPUT UM1Y,UM1Z,UM2Y,UM2Z
      OUTPUT UM3Y,UM3Z
      OUTPUT ISIDEL,THSLOS
      OUTPUT THSL,SLK,SLYO,SLZO
      OUTPUT THSLA,SLAK,SLAYO,SLAZO
      OUTPUT THSLS1,SLS1K,SLS1YO,SLS2ZO
      OUTPUT THSLS2,SLS2K,SLS2YO,SLS3ZO
      OUTPUT THSLS3,SLS3K,SLS3YO,SLS4ZO
      IGATHER = .FALSE.
      KGPASS=0
C
C     THIS AREA RESERVED FOR REINITIILIZING AFTER A RUN-TIME INPUT
C
   10 CONTINUE
      INPUT(IFILE) ←
      NUMRUN=NUMRUN+1
      DT=DT2M15*XSLOW
      DTO2=DT/2.
      TWODT=DT+DT
      DT2O4=DTO2*DTO2
      C1P=2.*UMP*ELP*(RP/(OPP*OP))**4
      C1T=2.*UMT*ELT*(RT/(OPT*OT))**4
      C3P=ELP/2./RP
      C3T=ELT/2./RT
      C2P=2.*C3P**2
      C2T=2.*C3T**2
      ELOD2P=C3P**2
      ELOD2T=C3P**2
      CLP=GPP-OP
      CLT=GPT-OT
      OMMRSQ=OMMR*OMMR
C     IF(ISIDEL.EQ.-1) SLK=0 ; SLS1K=0 ; SLS2K=0 ; SLS3K=0 ; SLAK=0.
      DO 801 K=1,MODC
  801 OMMCSQ(K)=OMMC(K)*OMMC(K)
   11 CONTINUE
C** ****************************************************
      CALL RSL(IEXIT,1)
      IF(IEXIT) CALL EXIT
C
C
      IF(KTAPE.NE.0) GO TO 710
      CALL RSL(ITAPE,ISLTAP)
      IF(ITAPE)GO TO 705
      IF(T.LT.TIMEON)GO TO 710
```

```
      C                                                                  319
            IDUMP=IDUMP+1                                                320
            TIMEON=TDUMP(IDUMP)                                          321
        79  IPASS=0                                                      322
            NPASS=0                                                      323
            YSLOW=0.
            KTAPE=-1                                                     324
            KDUMP=KDUMP+1                                                325
            KTEMP=KDUMP+IIDUMP                                           326
            CALL WCL(KTEMP)                                              327
      C                                                                  328
      C      WRITE HEADERS FOR THIS TIME-SLICE                           329
      C                                                                  330
            WRITE(MTAPE,750)NCHAN,IMAX,NMAX,T,DT,RUNID                   331
            WRITE(MTAPE,751)(AOUT(I),I=1,11)                             332
            WRITE(LPR,752)NCHAN,IMAX,NMAX,A,DTEMIS,RUNID
            WRITE(LPR,753)((IOUT(I),AOUT(I)),I=1,10)                     334
        7 C FORMAT(I2,2I4,2E20.8,A4)                                     335
        7 1 FORMAT(10A4)                                                 336
        7 2 FORMAT(//' ',I2,' CHANNELS/SAMPLE,   ',I4,' SAMPLES/RECORD,  '  337
           *,I4,' SAMPLES/TIME-SLICE. TIME',E14.7,' (WITH DT=',E14.7,')'  338
           *,'  RUN-ID= ',A4)                                            339
        7 3 FORMAT(' CHANNELS ',10('  (',I2,') ',A4))                    340
        7 C CONTINUE                                                     341
      C                                                                  342
            CALL DELTAS
      C
            PHIDXSQ= PHIDX*PHIDX                                         837
        26 1 PHIDXA=ABS(PHIDX)
            AKPY=(AKPYC+PHIDXA*(AKPY1+AKPY2*PHIDXA+AKPY3*PHIDXSQ))*AKPY4
            AKPZ=(AKPZC+PHIDXA*(AKPZ1+AKPZ2*PHIDXA+AKPZ3*PHIDXSQ))*AKPZ4
            AKTY=(AKTYC+PHIDXA*(AKTY1+AKTY2*PHIDXA+AKTY3*PHIDXSQ))*AKTY4
            AKTZ=(AKTZC+PHIDXA*(AKTZ1+AKTZ2*PHIDXA+AKTZ3*PHIDXSQ))*AKTZ4
      C
      C
      C     ENTER THIS SECTION IF STIFFNESS CONSTANTS FOR BEARINGS AND THEIR
      C     RESPECTIVE CARRIERS ARE TO BE CONSIDERED INDEPENDENTLY.
      C
      C     AK(P-T)(Y-Z)(C-4) ARE THE CURVE-FIT COEFFICIENTS FOR BEARINGS,
      C     BK(P-T)(Y-Z) ARE THE COEFFICIENTS FOR THE BEARING CARRIER...
      C
      C     IF THIS SECTION IS NOT USED, AJ(P-T)(Y-Z)(0-4) ARE THE CURVE-FIT
      C     COEFFICIENTS FOR THE COMBINED STIFFNESSES (BEARING AND CARRIER).
      C
            IF(IBSEPBC.EQ.0)GO TO 1300
            AKPY=AKPY*BKPY/(AKPY+BKPY)
            AKPZ=AKPZ*BKPZ/(AKPZ+BKPZ)
            AKTY=AKTY*BKTY/(AKTY+BKTY)
            AKTZ=AKTZ*BKTZ/(AKTZ+BKTZ)
       1300 CONTINUE
      C
      C
      C     KDUMP=1 IMPLIES INVALID CONDITION
```

```
C     KPUMP=2 IMPLIES HPFTP (W/ POSITIVE SPIN)
C     KPUMP=3 IMPLIES HPOTP (W/ NEGATIVE SPIN)
C
C     THERE IS A DIFFERENCE IN THE STRUCTURES OF THE BEARING/CARRIER
C     ASSEMBLY SIMULATION BETWEEN THE HPOTP AND THE HPFTP
C
      IF(KPUMP.EQ.2)KPY=AKPY;KPZ=AKPZ;KTY=AKTY;KTZ=AKTZ;KPPY=AKPPY;
     * KPPZ=AKPPZ;KPTY=AKPTY;KPTZ=AKPTZ
      IF(KPUMP.EQ.3)KPY=AKPPY;KPZ=AKPPZ;KTY=AKPTY;KTZ=AKPTZ;KPPY=AKPY;
     * KPPZ=AKPZ;KPTY=AKTY;KPTZ=AKTZ
C
C
      KB = AKB0+PHIDXA*(AKB1+PHIDXA*AKB2)
      CB = ACB0+PHIDXA*(ACB1+PHIDXA*CB2)
      KSA=SKA0+SKA1*PHIDXA+SKA2*PHIDZSQ
      GSA=(SGA0+SGA1*PHIDXA+SGA2*PHIDZSQ)
      CSA=SCA0+SCA1*PHIDXA+SCA2*PHIDZSQ
      KS1=SK10+SK11*PHIDXA+SK12*PHIDZSQ
      GS1=(SG10+SG11*PHIDXA+SG12*PHIDZSQ)
      CS1=SC10+SC11*PHIDXA+SC12*PHIDZSQ
      KS2=SK20+SK21*PHIDXA+SK22*PHIDZSQ
      GS2=(SG20+SG21*PHIDXA+SG22*PHIDZSQ)
      CS2=SC20+SC21*PHIDXA+SC22*PHIDZSQ
C
C     THIS SEAL IS NOT IN FUEL PUMP
      KS3=SK30+SK31*PHIDXA+SK32*PHIDZSQ
      (GS3=SG30+SG31*PHIDXA+SG32*PHIDZSQ)
      CS3=SC30+SC31*PHIDXA+SC32*PHIDZSQ
C
   26 3 GA=(GA0+PHIDXA*(GA1+PHIDXA*(GA3+PHIDXA*GA3+PHIDXSQ*GA4))))*BETA/RA
C
      IF(PHIX.GT.TWOPI) PHIX=PHIX-TWOPI                                 561
      IF(PHIX.LT.MTWPI) PHIX=PHIX-MTWPI                                 562
      SX= SIN(PHIX)                                                     563
      CX= COS(PHIX)                                                     564
      FLPY= PHIDXSQ*(UMPY*CX-UMPZ*SX)+PHIDDX*(UMPZ*CX+UMPY*SX)          565
      FUTY= PHIDXSQ*(UMTY*CX-UMTZ*SX)+PHIDDX*(UMTZ*CX+UMTY*SX)
      FLBY= PHIDXSQ*(UMBY*CX-UMBZ*SX)+PHIDDX*(UMBZ*CX+UMBY*SX)
      FUAY= PHIDXSQ*(UMAY*CX-UMAZ*SX)+PHIDDX*(UMAZ*CX+UMAY*SX)
      FLS1Y=PHIDXSQ*(UM1Y*CX-UM1Z*SX)+PHIDDX*(UM1Z*CX+UM1Y*SX)          569
      FLS2Y=PHIDXSQ*(UM2Y*CX-UM2Z*SX)+PHIDDX*(UM2Z*CX+UM2Y*SX)          570
C
C     THIS SEAL IS NOT IN FUEL PUMP
      FLS3Y=PHIDXSQ*(UM3Y*CX-UM3Z*SX)+PHIDDX*(UM3Z*CX+UM3Y*SX)          571
C
      FLPZ= PHIDXSQ*(UMPY*SX+UMPZ*CX)+PHIDDX*(UMPZ*SX-UMPY*CX)          572
      FUTZ= PHIDXSQ*(UMTY*SX+UMTZ*CX)+PHIDDX*(UMTZ*SX-UMTY*CX)          573
      FUBZ= PHIDXSQ*(UMBY*SX+UMBZ*CX)+PHIDDX*(UMBZ*SX-UMBY*CX)          574
      FLAZ= PHIDXSQ*(UMAY*SX+UMAZ*CX)+PHIDDX*(UMAZ*SX-UMAY*CX)          575
      FLS1Z=PHIDXSQ*(UM1Y*SX+UM1Z*CX)+PHIDDX*(UM1Z*SX-UM1Y*CX)          576
      FLS2Z=PHIDXSQ*(UM2Y*SX+UM2Z*CX)+PHIDDX*(UM2Z*SX-UM2Y*CX)          577
C
C     THIS SEAL IS NOT IN FUEL PUMP
```

```
      FUS3Z=PHIDXSQ*(UM3Y*SX+UM3Z*CX)+PHIDDX*(UM3Z*SX-UM3Y*CX)          578
C
C     ***************************************************************
C
C     THIS SECTION DETERMINES STATUS OF SQUEEZE-FILM DAMPING AT BEARINGS
C        ICAV = 2 MEANS NO SQUEEZE FILM DAMPING
C        ICAV = 1 MEANS SQUEEZE-FILM DAMPING WITH CAVITATION
C        ICAV = 0 MEANS SQUEEZE-FILM DAMPING WITHOUT CAVITATION
C
      FSFPY=0.
      FSFPZ=0.
      FSFTY=0.
      FSFTZ=0.
      IF(ICAV.EQ.1)C1=C1P,C2=C2P,C3=M3P,ELOD2=ELOD2P,EMAX=EMAXP         579
     *,CL=CLP
     *,CALL JOUR1(DELDPPY,DELDPPZ,DEUPPY,DELPPZ,0.,FSFPY,FSFPZ)         580
     *,C1=C1T,C2=C2T,C3=C3T,ELOD2=ELOD2T,EMAX=EMAXT                     581
     *,CL=CLT
     *,CALL JOUR1(DELDPTY,DELDPTZ,DEUPTY,DELPTZ,0.,FSFTY,FSFTZ)         582
      IF(ICAV.EQ.0)C1=C1P,C2=C2P,C3=M3P,ELOD2=ELOD2P,EMAX=EMAXP         583
     *,CL=CLP
     *,CALL JOUR2(DELDPPY,DELDPPZ,DEUPPY,DELPPZ,0.,FSFPY,FSFPZ)         584
     *,C1T=C1T,C2=C2T,C3=C3T,ELOD2=ELOD2T,EMAX=EMAXT                    585
     *,CL=CLT
     *,CALL JOUR2(DELDPTY,DELDPTZ,DEUPTY,DELPTZ,0.,FSFTY,FSFTZ)         586
      PSFP= FSFPY*DELDPY+FSFPZ*DELDPV
      PSFT= FSFTY*DELDTY+FSFTZ*DELDTV
C
C     ***************************************************************
C
C
C     SIDELOAD CALCULATIONS
C
      DO 1200 IP1=1,10
      GO TO (9000,2622,2623),KPUMP
 2622 IF(PHIDX.GT.TPHIDX(IP1))GO TO 1200
      GO TO 2601
 2623 IF(PHIDX.LE.TPHIDX(IP1))GO TO 1200
 2601 I=IP1-1
      IF(I.EQ.0) GO TO 1201
      TEMP=(PHIDX-TPHIDX(I))/(TPHIDX(IP1)-TPHIDX(I))                    591
      SLYC=TEMP*(SLY(IP1)-SLY(I))+SLP(I)   } At balance-piston          592
      SLZC=TEMP*(SLZ(IP1)-SLZ(I))+SLV(I)   }                            593
      SLS1YO=TEMP*(SLS1Y(IP1)-SLS1Y(S))+SLS1Y(I)   } S1                 594
      SLS1ZO=TEMP*(SLS1Z(IP1)-SLS1Z(S))+SLS1Z(I)   }                    595
      SLS2YO=TEMP*(SLS2Y(IP1)-SLS2Y(S))+SLS2Y(I)   } S2                 596
      SLS2ZO=TEMP*(SLS2Z(IP1)-SLS2Z(S))+SLS2Z(I)   }                    597
      SLAYO=TEMP*(SLAY(IP1)-SLAY(I))/SLAY(I)   } A                      600
      SLAZO=TEMP*(SLAZ(IP1)-SLAZ(I))/SLAZ(I)   }                        601
C
C     THIS SEAL IS NOT IN FUEL PUMP
      SLS3YO=TEMP*(SLS3Y(IP1)-SLS3Y(S))+SLS3Y(I)   } S3                 598
      SLS3ZO=TEMP*(SLS3Z(IP1)-SLS3Z(S))+SLS3Z(I)   }                    599
```

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```
C
C
C
C      THIS SECTION CALCULATES SIDELOIDS BASED ON ANGULAR DEVIATIONS
C         FROM CURRENT VALUES. TO ENAKLE, SET ISIDEL TO NON-ZERO
C         ISIDEL = -1 ALL SIDELOADS ARE ZERO
C         ISIDEL =  1 ALL SIDELOADS ARE RECALCULATED.
C
       IF(ISIDEL.EQ.0)GO TO 2150
       SLYT=SLYC
       SLZT=SLZC
       SLYC=(SLYT*COS(THSL+THSLOS)+SLYT*SIN(THSL+THSLOS))*SLK
       SLZC=(SLZT*COS(THSL+THSLOS)*SLPT*SIN(THSL+THSLOS))*SLK
       SLAYT=SLAYC
       SLAZT=SLAZC
       SLAYO=(SLAYT*COS(THSL+THSLOS)+SLAZT*SIN(THSL+THSLOS))*SLAK
       SLAZO=(SLAZT*COS(THSL+THSLOS)-SLAYT*SIN(THSL+THSLOS))*SLAK
       SLS1YT=SLS1YO
       SLS1ZT=SLS1ZO
       SLS1YO=(SLS1YT*COS(THSL+THSLOS)+SLS1ZT*SIN(THSL+THSLOS))*SLS1K
       SLS1ZO=(SLS1ZT*COS(THSL+THSLOS)-SLS1ZT*SIN(THSL+THSLOS))*SLS1K
       SLS2YT=SLS2YO
       SLS2ZT=SLS2ZO
       SLS2YO=(SLS2YT*COS(THSL+THSLOS)+SLS2ZT*SIN(THSL+THSLOS))*SLS2K
       SLS2ZO=(SLS2ZT*COS(THSL+THSLOS)-SLS2ZT*SIN(THSL+THSLOS))*SLS2K
C
C      THIS SEAL NOT IN FUEL PUMP
       SLS3YT=SLS3YO
       SLS3ZT=SLS3ZO
       SLS3YO=(SLS3YT*COS(THSL+THSLOS)+SLS3ZT*SIN(THSL+THSLOS))*SLS3K
       SLS3ZO=(SLS3ZT*COS(THSL+THSLOS)-SLS3ZT*SIN(THSL+THSLOS))*SLS3K
C
  2150 CONTINUE
C
C
C      ****************************************************************
       GO TO 1201                                                 602
  1200 CONTINUE
  1201 CONTINUE                                                   605
C
C
       FPY=-KPY*DELPPY-CPY*DELDPPY                                606
     *-KPPY*DPPPY-CPPY*CDPPPY         ?                           607
     *-CPDBY*(DELDPY*DELDPPY)                                     608
     *-AKPDBY*(DELPY*DELPPY)+FSPPY+FMAPPY                         609
       FPZ=-KPZ*DELPPZ-CPZ*DELDPPZ                                610
     *-KPPZ*DPPPZ-CPPZ*CDPPPZ                                     611
     *-CPDBZ*(DELDPZ*DELDPPZ)                                     612
     *-AKPDBZ*(DELPZ*DELPPZ)+FSPPZ+FMAPPZ                         613
       FTY=-KTY*DELPTY-CTY*DELDPTY                                614
     *-KPTY*DPPTY-CPTY*CDPPTY
     *-CTDBY*(CELDTY*DELDPTY)                                     616
     *-AKTDBY*(DELTY*DELPTY)+FSPTY+FMAPTY                         617
```

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      FTZ=-KTZ*DELPTZ-CTZ*DELDPTZ                                      618
     *-KPTZ*DPPTZ-CPTZ*DDPPTZ
     *-CTDBZ*(DELDTZ*DELDPTZ)                                          620
     *-AKTDBZ*(DELTZ*DELPTZ)+FSFTZ+FMAPTZ                              621
      PP= FPY*DELDPY+FPZ*DELDPZ
      PT= FTY*DELDTY+FTZ*DELDTZ
      FBX=-KB*DELBX-CB*DELDBX                                          622
      FBX=-KB*DELBX-CB*DELDBX+ABF*SX                                   623
      FBY=SLYC                                                         624
      FBZ=SLZC                                                         625
      FAY=-QA*DELAZ-KSA*DELAY-QSA*DEUAZ-CSA*DELDAY+SLAYO               626
      FAZ= QA*DELAY-KSA*DELAZ+QSA*DEUAY-CSA*DELDAZ+SLAZO               627
      FS1Y=-KS1*DELS1Y-GS1*DELS1Z-CS2*DELDS1Y                          628
     *+KS1*DES1Y+GS1*DES1Z                                             629
     *+SLS1YO                                                          630
      FS2Y=-KS2*DELS2Y-GS2*DELS2Z-CS3*DELDS2Y                          631
     *+SLS2YO                                                          632
C
C     THIS SEAL IS NOT IN FUEL PUMP
      FS3Y=-KS3*DELS3Y-GS3*DELS3Z-CS4*DELDS3Y                          633
     *+SLS3YO                                                          634
C
      FS1Z=-KS1*DELS1Z+GS1*DELS1Y-CS2*DELDS1Z                          635
     *+KS1*DES1Z-GS1*DES1Y                                             636
     *+SLS1ZO                                                          637
      FS2Z=-KS2*DELS2Z+GS2*DELS2Y-CS3*DELDS2Z                          638
     *+SLS2ZO                                                          639
C
C     THIS SEAL IS NOT IN FUEL PUMP
      FS3Z=-KS3*DELS3Z+GS3*DELS3Y-CS4*DELDS3Z                          640
     *+SLS3ZO                                                          641
C
      RS1=(SQRT(FS1Y*FS1Y+FS1Z*FS1Z))/FS1MAX                           642
      IF(RS1.GT.1.)TRS1=1.-RS1   ;   QKS1SQ=KS1*KS1+QS1*QS1            643
     *;FS1Y=FS1Y/RS1   ;   FS1Z=FS1Z/RS1                               644
     *;DES1Y=TRS1*(KS1*FS1Y-GS1*FS1Z)/QKS1SQ+DES1Y                     645
     *;DES1Z=TRS1*(KS1*FS1Z+GS1*FS1Y)/QKS1SQ+DES1Z                     646
      FRPY= FPY+FUPY                                                   647
      FRTY= FTY+FUTY                                                   648
      FRBY=FBY+FUBY                                                    649
      FRAY= FAY+FUAY                                                   650
      FRS1Y= FS1Y+FUS1Y                                                651
      FRS2Y= FS2Y+FUS2Y                                                652
      FRPZ= FPZ+FUPZ                                                   654
      FRTZ= FTZ+FUTZ                                                   655
      FRBZ=FBZ+FUBZ                                                    656
      FRAZ= FAZ+FUAZ                                                   657
      FRS1Z= FS1Z+FUS1Z                                                658
      FRS2Z= FS2Z+FUS2Z                                                659
C
C     THIS SEAL IS NOT IN FUEL PUMP
      FRS3Y= FS3Y+FUS3Y                                                653
C
```

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```
      FRS3Z= FS3Z+FUS3Z
      DO 200 I=1,9
      IF((T.LE.TIME(I)).OR.(T.GT.TIME(I+1))) GO TO 200
      DSPEED=(SPEED(I+1)-SPEED(I))/(TIME(I+1)-TIME(I))
      DSPEED=DSPEED*GSPEED
      CALL RSL(IWAIT,SLWAIT)
      IF(IWAIT) GO TO 202
      DSPEED=0.
      DO 203 J=1,9
  203 TIME(J)=TIME(J)+DT
      TIMEON=TIMEON+DT
      TF=TF+DT
      DO 213 J=1,3
  213 TCUMP(J)=TCUMP(J)+DT
      GO TO 204
  202 CALL RSL(IBACK,SLBACK)
      IF(IBACK) GO TO 204
      DSPEED=-DSPEED
      DO 205 J=1,9
  205 TIME(J)=TIME(J)+TWODT
      TF=TF+TWODT
      DO 215 J=1,3
  215 TCUMP(J)=TCUMP(J)+TWODT
      TIMEON=TIMEON+TWODT
  204 CONTINUE
      PHIDDX= DSPEED*TWOPI/60.
      TAUM= I1*PHIDDX
      GO TO 201
  200 CONTINUE
  201 CONTINUE
      XDD= FBX/M
      YDD= (FRPY+FRTY+FRAY+FRS1Y+FRS3Y+FRS3Y+FRBY)/M
      ZDD= (FRPZ+FRTZ+FRAZ+FRS1Z+FRS3Z+FRS3Z+FRBZ)/M
      PHIDDY= (-PHIDX*(I1*PHIDZ+GAMO*XIDY)-PHIDDX*(-I1*PHIZ+GAMO*XIY)
     *-LP*FRPZ-LT*FRTZ-LA*FRAZ-LS1*FRS1Z-LS2*FRS2Z-LS3*FRS3Z-LB*FRBZ)/I2
      PHIDDZ= (PHIDX*(I1*PHIDY-GAMO*XIDZ)
     *+LP*FRPY+LT*FRTY+LA*FRAY+LS1*FRS1Y+LS2*FRS2Y+LS3*FRS3Y+LB*FRBY)/I2
C     IF(IFLEX.EQ.0) GO TO 600
      XYTEMP=XIDY+PHIDX*XIZ
      XZTEMP=XIDZ-PHIDX*XIY
      XIDMAG=SQRT(XYTEMP*XYTEMP+XZTEMP*XZTEMP)+XIDC
      XIDDY=-TWOZETR*OMMR*PHIDX*XIZ
     *-PHIDX*(GAM1*XIDZ-GAMO*PHIDY)
     *+PHIRP*FRPY+PHIRT*FRTY+PHIRB*FRBY
     *+PHIRA*FRAY+PHIRS1*FRS1Y+PHIRS2*FRS2Y+PHIRS3*FRS3Y
     *-TWOZETR*OMMR*XIDY-OMMRSQ*XIY
     *-XMUK*XYTEMP/XIDMAG
      XIDDZ= TWOZETR*OMMR*PHIDX*XIY
     *-PHIDX*(-GAMO*PHIDZ-GAM1*XIDY)-PHIDDX*(-GAMO*PHIZ-GAM1*XIY)
     *+PHIRP*FRPZ+PHIRT*FRTZ+PHIRB*FRBZ
     *+PHIRA*FRAZ+PHIRS1*FRS1Z+PHIRS2*FRS2Z+PHIRS3*FRS3Z
     *-TWOZETR*OMMR*XIDZ-OMMRSQ*XIZ
     *-XMUK*XZTEMP/XIDMAG
```

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```
      A1= A2= A3= A4= A5= A6= A7= 0.0                                  713
      DO 100 I= 1,MODE                                                 714
      ETADD(I)=-PHICPY(I)*FPY-PHICBY(I)*FBY-PHICTY(I)*FTY-PHICAY(I)*FAY 715
     *-PHICPZ(I)*FPZ-PHICTZ(I)*FTZ-PHICBZ(I)*FBZ-PHICAZ(I)*FAZ         716
     *-PHICS1Y(I)*FS1Y-PHICS2Y(I)*FS2Y-PHICS3Y(I)*FS3Y                 717
     *-PHICS1Z(I)*FS1Z-PHICS2Z(I)*FS2Z-PHICS3Z(I)*FS3Z                 718
     *-PSICAX(I)*TAUM                                                  719
     *-PHICBX(I)*FBX
     *-TWOZETC(I)*OHMC(I)*ETAD(I)-OHMCSQ(I)*ETA(I)                     721
      ETAD(I)= ETAD(I)+DT02*(3.*ETADD(I)-ETADDB(I))                    722
      ETA(I)= ETA(I)+DT02*(ETAD(I)+ETADB(I))                           723
      ETADB(I)= ETAD(I)
      A1= A1+AC1(I)*ETADD(I)                                           726
      A2= A2+AC2(I)*ETADD(I)                                           727
      A3= A3+AC3(I)*ETADD(I)                                           728
      A4= A4+AC4(I)*ETADD(I)
      A5= A5+AC5(I)*ETADD(I)
      A6= A6+AC6(I)*ETADD(I)
      A7= A7+AC7(I)*ETADD(I)                                           732
      ETADDB(I)= ETADD(I)                                              724
  100 CONTINUE                                                         733
      XIDY= XIDY+DT02*(3.*XIDDY-XIDDYB)                                734
      XIDZ= XIDZ+DT02*(3.*XIDDZ-XIDDZB)                                735
      XD= XD+DT02*(3.*XDD-XDDB)                                        736
      YD= YD+DT02*(3.*YDD-YDDB)
      ZD= ZD+DT02*(3.*ZDD-ZDDB)
      PHIDX= PHIDX+DT02*(3.*PHIDDX-PHIDDXB)                            739
      PHIDY= PHIDY+DT02*(3.*PHIDDY-PHIDDYB)                            740
      PHIDZ= PHIDZ+DT02*(3.*PHIDDZ-PHIDDZB)                            741
      XIY= XIY+DT02*(XIDY+XIDYB)
      XIZ= XIZ+DT02*(XIDZ+XIDZB)
      X= X+DT02*(XD+XDB)                                               744
      Y= Y+DT02*(YD+YDB)                                               745
      Z= Z+DT02*(ZD+ZDB)                                               746
      PHIX= PHIX+DT02*(PHIDX+PHIDXB)                                   747
      PHIY= PHIY+DT02*(PHIDY+PHIDYB)                                   748
      PHIZ= PHIZ+DT02*(PHIDZ+PHIDZB)                                   749
      XIDDYB= XIDDY                                                    766
      XIDDZB= XIDDZ                                                    767
      XIDYB= XIDY                                                      768
      XIDZB= XIDZ                                                      769
      XDDB= XDD                                                        770
      YDDB= YDD                                                        771
      ZDDB= ZDD                                                        772
      XDB= XD                                                          773
      YDB= YD                                                          774
      ZDB= ZD                                                          775
      PHIDDXB= PHIDDX                                                  776
      PHIDDYB= PHIDDY                                                  777
      PHIDDZB= PHIDDZ                                                  778
      PHIDXB= PHIDX                                                    779
      PHIDYB= PHIDY                                                    780
      PHIDZB= PHIDZ                                                    781
```

```
      GO TO 601
  600 CONTINUE
      XD= XD+DT*XDD
      YD= YD+DT*YDD
      ZD= ZD+DT*ZDD
      X= X+DT*XD
      Y= Y+DT*YD
      Z= Z+DT*ZD
      PHIDX= PHIDX+DT*PHIDDX
      PHIDY= PHIDY+DT*PHIDDY
      PHIDZ= PHIDZ+DT*PHIDDZ
      PHIX= PHIX+DT*PHIDX
      PHIY= PHIY+DT*PHIDY
      PHIZ= PHIZ+DT*PHIDZ
  601 CONTINUE
      DELS1=SQRT(DELS1Y*DELS1Y+DELS1Z*DELS1Z)
      DELS2=SQRT(DELS2Y*DELS2Y+DELS2Z*DELS2Z)
      DELS3=SQRT(DELS3Y*DELS3Y+DELS3Z*DELS3Z)
C
C
C     ************************************************************
C
      DAC( 1)= A1
      DAC( 2)= A2
      DAC( 3)= A3
      DAC( 4)= A4
      DAC( 5)= A5
      DAC( 6)= A6
      DAC(7)= PSFP
      DAC(8)= PSFT
C
      DAC( 9)= DELS1Y
      DAC(10)=DELS1Z
      DAC(11)=DELAY
      DAC(12)=DELAZ
      DAC(13)=DELS3Y
      DAC(14)=DELS3Z
      DAC(15)= PF
      DAC(16)= PT
C
      DAC(17)= DELP
      DAC(18)= DELT
      DAC(19)= DELPY
      DAC(20)= DELPZ
      DAC(21)= DELTY
      DAC(22)= DELTZ
      DAC(23)=FSFPY
      DAC(24)=FSFPZ
C
      DAC(25)= PHIDX
      DAC(26)= SQRT(FPY*FPY+FPZ*FPZ)
      DAC(27)= SQRT(FTY*FTY+FTZ*FTZ)
      DAC(28)=FS1Y
```

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```
      DAC(29)=FGIZ
      DAC(30)=FSFIY
      DAC(31)=FSFTZ
      DAC(32)= DELA
C
      DAC(33)=A7
      DAC(34)= FBX
      DAC(35)=VWP
      DAC(36)=VWT
      DAC(37)=ETA(1)
      DAC(38)=ETA(2)
      DAC(39)=ETA(3)
      DAC(40)=ETA(4)
C
      DAC(41)=ETA(5)
      DAC(42)=ETA(6)
      DAC(43)=XIY
      DAC(44)=XIZ
      DAC(45)=FPY
      DAC(46)=FPZ
      DAC(47)=Y
      DAC(48)=Z
C
      DAC(49)= FIY
      DAC(50)= FIZ
      DAC(51)=PHIY
      DAC(52)=PHIZ
C
      DAC(53)=DELB2Y
      DAC(54)=DELB2Z
      DAC(55)=DELB2
      DAC(56)=DELB1
C
      DAC(57)=DELB3
      DAC(58)=ETA(7)
      DAC(59)=ETA(8)
      DAC(60)=ETA(9)
      DAC(61)=ETA(10)
      DAC(62)=DELBX
C
C
C
      DO 900 I=1,32
      J=ICHANL(I)
      DAX(I)=DAC(J)
  900 CONTINUE
C
C
C
C
C     THE FOLLOWING CODING IS EXECUTED EACH PASS TO KEEP THE SIMULATION
C     RUNNING AT AN EVEN PACE. HOWEVER, NO TAPE WRITING OCCURS UNLESS
C     THE FLAG (KTAPE) IS SET TO NONZERO...
```

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```
C                                                                   842
      IF(KTAPE.NE.0)NPASS=NPASS+1                                   843
      YSLOW=YSLOW+XSLOW
      IF(YSLOW.GT..98)IPASS=IPASS+1
      IF(KTAPE.GT.0)GO TO 701                                       845
      BUFFRA(1,IPASS)=T                                             846
      DO 700  I=2,NCHAN                                             847
      J=IOUT(I)                                                     848
  700 BUFFRA(I,IPASS)=DA1(J)                                        849
      IF(IPASS.LT.IMAX)GO TO 707                                    850
      IF(KTAPE.EQ.0)GO TO 720
      CALL BUFFOUT(MTAPE,1,BUFFRA,IMIX10)
      YSLOW=0.
  720 KTAPE=-KTAPE
      IPASS=0                                                       853
      GO TO 707                                                     854
  701 CONTINUE                                                      855
      BUFFRB(1,IPASS)=T                                             856
      DO 703  I=2,NCHAN                                             857
      J=IOUT(I)                                                     858
  703 BUFFRB(I,IPASS)=DA1(J)                                        859
      IF(IPASS.LT.IMAX)GO TO 707                                    860
      IF(KTAPE.EQ.0)GO TO 721
      YSLOW=0.
      CALL BUFFOUT(MTAPE,1,BUFFRB,IMIX10)
  721 KTAPE=-KTAPE
      IPASS=0                                                       863
      IF(NPASS.LT.NMAX)GO TO 707                                    864
C      THIS TIME-SLICE FINISHED. RE-INITIALIZE COUNTERS             865
      NPASS=0                                                       866
      ENDFILE(MTAPE)                                                867
      KTAPE=0                                                       868
  707 CONTINUE                                                      869
C                                                                   870
      DO 300 I=1,32                                                 871
      IF(ABS(DA1(I)).GE.SF1(I)) DA1(I)= SIGN(SF1(I),DA1(I))*.9999   872
  300 CONTINUE                                                      873
      IPULSE= T/TPULSE                                              874
      RPULSE= IPULSE                                                875
      REM= T-TPULSE*RPULSE                                          876
      CALL WDW(IWORD,1)                                             877
      IF(REM.LE.DT) CALL WCL(IIPULS)                                878
      CALL WDAC(C,32,DA1,SF1)                                       879
      IF(T.GE.TF) CALL WDAC(C,32,ZERN,SF1), CALL EXIT               880
      T= T+DT                                                       881
      GO TO 1                                                       882
   50 CALL EXIT
      END                                                           884
```

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NAME	TYPE	CLASS	HEX LOC	DEC WORDS	NAME	TYPE	CLASS	HEX LOC	DEC WORDS	NAME	TYPE	CLASS	HEX LOC	DEC WORDS
ABF	R	SCALR	00F3B V	1	ABS	R	SPROG	INTRIN		ACB0	R	SCALR	00F19 V	1
ACB1	R	SCALR	00F1A V	1	ACB2	R	SCALR	00F1B V	1	AC1	R	ARRAY	006D8 L	10
AC2	R	ARRAY	006E2 L	10	AC3	R	ARRAY	006EC L	10	AC4	R	ARRAY	006F6 L	10
AC5	R	ARRAY	00700 L	10	AC6	R	ARRAY	0070A L	10	AC7	R	ARRAY	00714 L	10
AIR1	R	ARRAY	0077C L	15	AIR2	R	ARRAY	0078B L	15	AIR3	R	ARRAY	0079A L	15
AKB0	R	SCALR	00F16 V	1	AKB1	R	SCALR	00F17 V	1	AKB2	R	SCALR	00F18 V	1
AKPDBY	R	SCALR	00F37 V	1	AKPDBZ	R	SCALR	00F38 V	1	AKPPY	R	SCALR	00F0E V	1
AKPPZ	R	SCALR	00F0F V	1	AKPTY	R	SCALR	00F10 V	1	AKPTZ	R	SCALR	00F11 V	1
AKPY	R	SCALR	00F4C V	1	AKPY0	R	SCALR	00E79 V	1	AKPY1	R	SCALR	00E7A V	1
AKPY2	R	SCALR	00E7B V	1	AKPY3	R	SCALR	00E7C V	1	AKPY4	R	SCALR	00ECC V	1
AKPZ	R	SCALR	00F4D V	1	AKPZ0	R	SCALR	00E7D V	1	AKPZ1	R	SCALR	00E7E V	1
AKPZ2	R	SCALR	00E7F V	1	AKPZ3	R	SCALR	00E80 V	1	AKPZ4	R	SCALR	00ECD V	1
AKTDBY	R	SCALR	00F39 V	1	AKTDBZ	R	SCALR	00F3A V	1	AKTY	R	SCALR	00F4E V	1
AKTY0	R	SCALR	00E81 V	1	AKTY1	R	SCALR	00E82 V	1	AKTY2	R	SCALR	00E83 V	1
AKTY3	R	SCALR	00E84 V	1	AKTY4	R	SCALR	00ECE V	1	AKTZ	R	SCALR	00F4F V	1
AKTZ0	R	SCALR	00E85 V	1	AKTZ1	R	SCALR	00E86 V	1	AKTZ2	R	SCALR	00E87 V	1
AKTZ3	R	SCALR	00E88 V	1	AKTZ4	R	SCALR	00ECF V	1	AMR	R	ARRAY	0076D L	15
ADLT	I	ARRAY	00E26 V	10	APUMP	R	ARRAY	00E35 V	3	A1	R	SCALR	00FA1 V	1
A2	R	SCALR	00FA2 V	1	A3	R	SCALR	00FA3 V	1	A4	R	SCALR	00FA4 V	1
A5	R	SCALR	00FA5 V	1	A6	R	SCALR	00FA6 V	1	A7	R	SCALR	00FA7 V	1
BENDING		SPROG	EXTERN		BETA	R	SCALR	00F08 V	1	BKPY	R	SCALR	00EB5 V	1
BKPZ	R	SCALR	00EB6 V	1	BKTY	R	SCALR	00EB7 V	1	BKTZ	R	SCALR	00EB8 V	1
BUFFOLT		SPROG	EXTERN		BUFFRA	R	ARRAY	0041C V	1280	BUFFRB	R	ARRAY	0091C V	1280
CAC1	R	ARRAY	0071E L	3	CAC2	R	ARRAY	00721 L	3	CAC3	R	ARRAY	00724 L	3
CAC4	R	ARRAY	00727 L	3	CAC5	R	ARRAY	0072A L	3	CAC6	R	ARRAY	0072D L	3
CAC7	R	ARRAY	00730 L	3	CB	R	SCALR	00F50 V	1	CL	R	SCALR	00000 L	1
CLF	R	SCALR	00F03 V	1	CLT	R	SCALR	00F04 V	1	CM	R	SCALR	00EEB V	1
COS	R	SPROG	INTRIN		CPDBY	R	SCALR	00F1C V	1	CPDBZ	R	SCALR	00F1D V	1
CPPY	R	SCALR	00E89 V	1	CPPZ	R	SCALR	00E8A V	1	CPTY	R	SCALR	00E8B V	1
CPTZ	R	SCALR	00E8C V	1	CPY	R	SCALR	00F12 V	1	CPZ	R	SCALR	00F13 V	1
CSA	R	SCALR	00F53 V	1	CS1	R	SCALR	00F55 V	1	CS2	R	SCALR	00F57 V	1
CS3	R	SCALR	00F[illegible]9 V	1	CTDBY	R	SCALR	00F1E V	1	CTDBZ	R	SCALR	00F1F V	1
CTY	R	SCALR	00F14 V	1	CTZ	R	SCALR	00F15 V	1	CX	R	SCALR	00F5C V	1
C1	R	SCALR	00001 L	1	C1P	R	SCALR	00EFB V	1	C1T	R	SCALR	00EFC V	1
C2	R	SCALR	00002 L	1	C2P	R	SCALR	00EFF V	1	C2T	R	SCALR	00F00 V	1
C3	R	SCALR	00003 L	1	C3P	R	SCALR	00EFD V	1	C3T	R	SCALR	00EFE V	1
DAC	R	ARRAY	0030E V	64	DAC1	R	ARRAY	00733 L	3	DAC2	R	ARRAY	00736 L	3
DAC3	R	ARRAY	00739 L	3	DAC4	R	ARRAY	0073C L	3	DAC5	R	ARRAY	0073F L	3
DAC6	R	ARRAY	00742 L	3	DAC7	R	ARRAY	00745 L	3	DAI	R	ARRAY	00020 V	32
DAIMAX	R	ARRAY	001CE V	32	DAIMIN	R	ARRAY	0012E V	32	DAIMNAVG	R	ARRAY	0016E V	32
DAIMXAVG	R	ARRAY	0014E V	32	DCRTST	R	SCALR	00EDD V	1	DDPPY	R	SCALR	00051 L	1
DDPPZ	R	SCALR	00052 L	1	DDPPTY	R	SCALR	0005E L	1	DDPPTZ	R	SCALR	0005F L	1
DELA	R	SCALR	0000F L	1	DELAY	R	SCALR	00004 L	1	DELAZ	R	SCALR	00005 L	1
DELBX	R	SCALR	00006 L	1	DELDAY	R	SCALR	00016 L	1	DELDAZ	R	SCALR	00017 L	1
DELCBX	R	SCALR	0001B L	1	DELDPPY	R	SCALR	0004F L	1	DELDPPZ	R	SCALR	00050 L	1
DELDPTY	R	SCALR	0005C L	1	DELDPTZ	R	SCALR	0005D L	1	DELDPY	R	SCALR	00011 L	1
DELDPZ	R	SCALR	00012 L	1	DELDS1Y	R	SCALR	00018 L	1	DELDS1Z	R	SCALR	0001B L	1
DELDS2Y	R	SCALR	00019 L	1	DELDS2Z	R	SCALR	0001C L	1	DELDS3Y	R	SCALR	0001A L	1
DELDS3Z	R	SCALR	0001D L	1	DELDTY	R	SCALR	00013 L	1	DELDTZ	R	SCALR	00014 L	1
DELF	R	SCALR	0000D L	1	DELPPY	R	SCALR	0004A L	1	DELPPZ	R	SCALR	0004B L	1

DELFTY	R	SCALR	00057	L	1	DELPTZ	R	SCALR	00058	L	1	DELPY	R	SCALR	00000	L	1
DELFZ	R	SCALR	000C1	L	1	DELS1	R	SCALR	00FB8	V	1	DELS1Y	R	SCALR	00007	L	1
DELS1Z	R	SCALR	0000A	L	1	DELS2	R	SCALR	00F89	V	1	DELS2Y	R	SCALR	00008	L	1
DELS2Z	R	SCALR	0000B	L	1	DELS3	R	SCALR	00EBA	V	1	DELS3Y	R	SCALR	00009	L	1
DELS3Z	R	SCALR	0000C	L	1	DELT	R	SCALR	0000E	L	1	DELTAB		SPROG	EXTERN		
DELTY	R	SCALR	000C2	L	1	DELTZ	R	SCALR	00003	L	1	DES1Y	R	SCALR	00EBA	V	1
DES1Z	R	SCALR	00EBB	V	1	DMIN	R	SCALR	00010	L	1	DPPPY	R	SCALR	0004D	L	1
DPPFZ	R	SCALR	0004E	L	1	DPPTY	R	SCALR	0005A	L	1	DPPTZ	R	SCALR	0005B	L	1
DSPEEC	R	SCALR	00F9B	V	1	DT	R	SCALR	00001	L	1	DT02	R	SCALR	00003	L	1
DT2P15	R	SCALR	00EC8	V	1	DT204	R	SCALR	00004	L	1	ELAPTIME	R	SCALR	00F3C	V	1
ELOD2	R	SCALR	00004	L	1	ELOD2P	R	SCALR	00E01	V	1	ELODET	R	SCALR	00F02	V	1
ELF	R	SCALR	00EC0	V	1	ELT	R	SCALR	00EC1	V	1	EMAX	R	SCALR	00006	L	1
EMAXF	R	SCALR	00FCA	V	1	EMAXT	R	SCALR	00ECB	V	1	ETA	R	ARRAY	00032	L	10
ETAB	R	ARRAY	000DC	V	10	ETABB	R	ARRAY	000EA	V	10	ETAD	R	ARRAY	0003C	L	10
ETADB	R	ARRAY	000D2	V	10	ETADBB	R	ARRAY	000F0	V	10	ETADD	R	ARRAY	000BE	V	10
ETADDB	R	ARRAY	000C8	V	10	ETADDBB	R	ARRAY	000E6	V	10	EXIT		SPROG	EXTERN		
FAY	R	SCALR	00F82	V	1	FAZ	R	SCALR	00F83	V	1	FBX	R	SCALR	00F7F	V	1
FBY	R	SCALR	00F80	V	1	FBZ	R	SCALR	00F81	V	1	FCAPPY	R	SCALR	00EE0	V	1
FCAPPZ	R	SCALR	00EE1	V	1	FCAPTY	R	SCALR	00EE2	V	1	FCAPTZ	R	SCALR	00EE3	V	1
FEEC	R	ARRAY	00352	L	720	FEER	R	ARRAY	0003C	L	60	FPY	R	SCALR	00E79	V	1
FPZ	R	SCALR	00F7A	V	1	FRAY	R	SCALR	00F90	V	1	FRAZ	R	SCALR	00F96	V	1
FRBY	R	SCALR	00E8F	V	1	FRBZ	R	SCALR	00E95	V	1	FRPY	R	SCALR	00F8D	V	1
FRPZ	R	SCALR	00F93	V	1	FRS1Y	R	SCALR	00F91	V	1	FRS1Z	R	SCALR	00F97	V	1
FRS2Y	R	SCALR	00E92	V	1	FRS2Z	R	SCALR	00F98	V	1	FRS3Y	R	SCALR	00F99	V	1
FRS3Z	R	SCALR	00F9A	V	1	FRTY	R	SCALR	00F8E	V	1	FRTZ	R	SCALR	00F94	V	1
FSEPY	R	SCALR	00EC4	V	1	FSEPZ	R	SCALR	00EC5	V	1	FSETY	R	SCALR	00EC6	V	1
FSETZ	R	SCALR	00EC7	V	1	FS1MAX	R	SCALR	00EBC	V	1	FS1Y	R	SCALR	00F84	V	1
FS1Z	R	SCALR	00E87	V	1	FS2Y	R	SCALR	00F85	V	1	FS2Z	R	SCALR	00F88	V	1
FS3Y	R	SCALR	00F86	V	1	FS3Z	R	SCALR	00F89	V	1	FTY	R	SCALR	00F7B	V	1
FTZ	R	SCALR	00F7C	V	1	FUAY	R	SCALR	00E60	V	1	FUAZ	R	SCALR	00F67	V	1
FUBY	R	SCALR	00F5F	V	1	FUBZ	R	SCALR	00F66	V	1	FUPY	R	SCALR	00F5D	V	1
FUPZ	R	SCALR	00E64	V	1	FUS1Y	R	SCALR	00E61	V	1	FUS1Z	R	SCALR	00E68	V	1
FUS2Y	R	SCALR	00F62	V	1	FUS2Z	R	SCALR	00F69	V	1	FUS3Y	R	SCALR	00F63	V	1
FUS3Z	R	SCALR	00E6A	V	1	FUTY	R	SCALR	00E5E	V	1	FUTZ	R	SCALR	00F65	V	1
GAMC	R	SCALR	00EEC	V	1	GAM1	R	SCALR	00EED	V	1	GP	R	SCALR	00048	L	1
GFF	R	SCALR	00047	L	1	GPT	R	SCALR	00054	L	1	GSPEED	R	SCALR	00EB9	V	1
GT	R	SCALR	00085	L	1	I	I	SCALR	00EE6	V	1	IBACK	L	SCALR	00E3B	V	1
IBIAS	I	ARRAY	0006C	V	64	IBSEPBC	I	SCALR	00EB4	V	1	ICA	I	SCALR	0062B	L	1
ICARD	I	ARRAY	0018E	V	320	ICARDS	L	SCALR	00E39	V	1	ICAV	I	SCALR	00EBD	V	1
ICB	I	SCALR	0062A	L	1	ICHNNL	I	ARRAY	0038E	V	32	ICLS	I	SCALR	00F05	V	1
ICF	I	SCALR	0062C	L	1	ICS1	I	SCALR	0062E	L	1	ICS2	I	SCALR	0062F	L	1
ICS3	I	SCALR	00630	L	1	ICT	I	SCALR	0062D	L	1	IDCTST	I	SCALR	00EDE	V	1
ICLMP	I	SCALR	00EF5	V	1	IEXIT	L	SCALR	00E6B	V	1	IFILE	I	SCALR	00EF8	V	1
IGATHER	L	SCALR	00E3E	V	1	IIDUMP	I	SCALR	00E6C	V	1	IIPULS	I	SCALR	00E6D	V	1
IMAX	I	SCALR	00E76	V	1	IMAX10	I	SCALR	00EF2	V	1	IOUT	I	ARRAY	00E1C	V	10
IPASS	I	SCALR	00E47	V	1	IPULSE	I	SCALR	00F88	V	1	IP1	I	SCALR	00F6D	V	1
IRA	I	SCALR	0062B	L	1	IRB	I	SCALR	00626	L	1	IREMOD	L	SCALR	00E3C	V	1
IRF	I	SCALR	00623	L	1	IRS1	I	SCALR	00627	L	1	IRS2	I	SCALR	00628	L	1
IRS3	I	SCALR	00629	L	1	IRT	I	SCALR	00624	L	1	ISIDEL	I	SCALR	00ED0	V	1
ISLIAF	I	SCALR	00E22	V	1	ITAPE	L	SCALR	00E38	V	1	ITOF	L	SCALR	00E3D	V	1
ITYPE	I	SCALR	00E73	V	1	IWAIT	L	SCALR	00E3A	V	1	IWORD	I	SCALR	00E6E	V	1
I1	R	SCALR	00E65	V	1	I2	R	SCALR	00E64	V	1	J	I	SCALR	00EE5	V	1
JAC1	I	SCALR	00748	L	1	JAC2	I	SCALR	00749	L	1	JAC3	I	SCALR	0074A	L	1

JAC4	I	SCALR	0074B	L	1	JAC5	I	SCALR	0074C	L	1	JAC6	I	SCALR	0074D	L	1
JAC7	I	SCALR	0074E	L	1	JNTC	I	SCALR	00E07	V	1	JNTR	I	SCALR	00EF1	V	1
JOLR1		SPROG	EXTERN			JOUR2		SPROG	EXTERN			JREMOD	I	SCALR	00EE7	V	1
K	I	SCALR	00EE9	V	1	KB	R	SCALR	00E61	V	1	KCHAN	I	SCALR	00E78	V	1
KCLMP	I	SCALR	00EF3	V	1	KOPASS	I	SCALR	00EEF	V	1	KPPY	R	SCALR	00E66	V	1
KFFZ	R	SCALR	00E67	V	1	KPTY	R	SCALR	00E68	V	1	KPTZ	R	SCALR	00E69	V	1
KFLMP	I	SCALR	00EE4	V	1	KPY	R	SCALR	00E5B	V	1	KPZ	R	SCALR	00E5C	V	1
KSA	I	SCALR	00E51	V	1	KS1	R	SCALR	00E5F	V	1	KS2	R	SCALR	00E60	V	1
KS3	R	SCALR	00E46	V	1	KTAPE	I	SCALR	00EF4	V	1	KTEMP	I	SCALR	00F49	V	1
KTY	R	SCALR	00E5D	V	1	KTZ	R	SCALR	00E5E	V	1	KVWPT	I	SCALR	00E45	V	1
L	I	SCALR	00EF7	V	1	LA	R	SCALR	00026	L	1	LB	R	SCALR	00E62	V	1
LF	R	SCALR	00024	L	1	LPR	I	SCALR	00E74	V	1	LS	R	ARRAY	00E47	V	20
LS1	R	SCALR	00027	L	1	LS2	R	SCALR	00028	L	1	LS3	R	SCALR	00029	L	1
LT	R	SCALR	00025	L	1	M	R	SCALR	00E63	V	1	MAXBPASS	I	SCALR	00EF0	V	1
MCDC	I	SCALR	00622	L	1	MODR	I	SCALR	00F06	V	1	MTAPE	I	SCALR	00E71	V	1
MTMF1	R	SCALR	00E6A	V	1	NCHAN	I	SCALR	00E77	V	1	NMAX	I	SCALR	00E75	V	1
NPASS	I	SCALR	00F48	V	1	NUMLINES	I	SCALR	00EDF	V	1	NUMRUN	I	SCALR	00EEE	V	1
OHHC	R	ARRAY	0074F	L	10	OHHCSQ	R	ARRAY	000A0	V	10	OHHR	R	SCALR	007A9	L	1
OHHRSQ	R	SCALR	007AA	L	1	PHIC	R	ARRAY	00078	L	720	PHICAY	R	ARRAY	006[illegible]	L	10
PHICAZ	R	ARRAY	0068B	L	10	PHICBX	R	ARRAY	00631	L	10	PHICBY	R	ARRAY	006[illegible]	L	10
PHICBZ	R	ARRAY	00645	L	10	PHICPY	R	ARRAY	00659	L	10	PHICPZ	R	ARRAY	00663	L	10
PHICS1Y	R	ARRAY	00695	L	10	PHICS1Z	R	ARRAY	0069F	L	10	PHICS2Y	R	ARRAY	006A9	L	10
PHICS2Z	R	ARRAY	006B3	L	10	PHICS3Y	R	ARRAY	006BD	L	10	PHICS3Z	R	ARRAY	006C7	L	10
PHICTY	R	ARRAY	0066D	L	10	PHICTZ	R	ARRAY	00677	L	10	PHIDDX	R	SCALR	00F30	V	1
PHIDDXB	R	SCALR	00FAD	V	1	PHIDDY	R	SCALR	00F33	V	1	PHIDDYB	R	SCALR	00FAE	V	1
PHIDDZ	R	SCALR	00F34	V	1	PHIDDZB	R	SCALR	00FAF	V	1	PHIDX	R	SCALR	00F31	V	1
PHIDXA	R	SCALR	00F4B	V	1	PHIDXB	R	SCALR	00FB5	V	1	PHIDXSQ	R	SCALR	00F4A	V	1
PHIDY	R	SCALR	0002D	L	1	PHIDYB	R	SCALR	00FB6	V	1	PHIDZ	R	SCALR	0002C	L	1
PHIDZB	R	SCALR	00FB7	V	1	PHIR	R	ARRAY	00000	L	60	PHIRA	R	SCALR	006D3	L	1
PHIRB	R	SCALR	006D4	L	1	PHIRP	R	SCALR	006D1	L	1	PHIRS1	R	SCALR	006D5	L	1
PHIRS2	R	SCALR	006D6	L	1	PHIRS3	R	SCALR	006D7	L	1	PHIRT	R	SCALR	006D2	L	1
PHIX	R	SCALR	00F32	V	1	PHIY	R	SCALR	0002B	L	1	PHIZ	R	SCALR	0002A	L	1
PI2	R	SCALR	00005	L	1	PF	R	SCALR	00F7D	V	1	PSFP	R	SCALR	00F6B	V	1
PSFT	R	SCALR	00F6C	V	1	PSICAX	R	ARRAY	0064F	L	10	PSICBX	R	ARRAY	00348	L	10
PT	R	SCALR	00F7E	V	1	QA	R	SCALR	00F5A	V	1	QA0	R	SCALR	00F09	V	1
QA1	R	SCALR	00FCA	V	1	QA2	R	SCALR	00F0B	V	1	QA3	R	SCALR	00F0C	V	1
QA4	R	SCALR	00FCD	V	1	QKS1SQ	R	SCALR	00F8C	V	1	QSA	R	SCALR	00F52	V	1
QS1	R	SCALR	00E54	V	1	QS2	R	SCALR	00E56	V	1	QS3	R	SCALR	00E58	V	1
R	R	ARRAY	00759	L	20	REM	R	SCALR	00FBD	V	1	RP	R	SCALR	00EBE	V	1
REFLSE	R	SCALR	00FBC	V	1	RSL		SPROG	EXTERN			RS1	R	SCALR	00F8A	V	1
RT	R	SCALR	00EBF	V	1	RUNID	R	SCALR	00EE8	V	1	SCALE	R	ARRAY	0034E	V	64
SCAC	R	SCALR	00E93	V	1	SCA1	R	SCALR	00E94	V	1	SCA2	R	SCALR	00E95	V	1
SC1C	R	SCALR	00E9C	V	1	SC11	R	SCALR	00E9D	V	1	SC12	R	SCALR	00E9E	V	1
SC2C	R	SCALR	00EA5	V	1	SC21	R	SCALR	00EA6	V	1	SC22	R	SCALR	00EA7	V	1
SC3C	R	SCALR	00EAE	V	1	SC31	R	SCALR	00EAF	V	1	SC32	R	SCALR	00EB0	V	1
SF1	R	ARRAY	00040	V	32	SIGN	R	SPROG	INTRIN			SIN	R	SPROG	INTRIN		
SKAC	R	SCALR	00E8D	V	1	SKA1	R	SCALR	00E8E	V	1	SKA2	R	SCALR	00E8F	V	1
SK1C	R	SCALR	00E96	V	1	SK11	R	SCALR	00E97	V	1	SK12	R	SCALR	00E98	V	1
SK2C	R	SCALR	00E9F	V	1	SK21	R	SCALR	00EA0	V	1	SK22	R	SCALR	00EA1	V	1
SK3C	R	SCALR	00EA8	V	1	SK31	R	SCALR	00EA9	V	1	SK32	R	SCALR	00EAA	V	1
SLAK	R	SCALR	00ED5	V	1	SLAY	R	ARRAY	00408	V	10	SLAYT	R	SCALR	00F71	V	1
SLAYC	R	SCALR	00F3F	V	1	SLAZ	R	ARRAY	00412	V	10	SLAZT	R	SCALR	00F72	V	1
SLAZC	R	SCALR	00F40	V	1	SLBACK	I	SCALR	00E44	V	1	SLCARD	I	SCALR	00E43	V	1

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ORIGINAL PAGE IS
OF POOR QUALITY

SLCATHER	I	SCA R	00E3F V	1	SLK	R	SCALR	00ED1 V	1	SLRMOD	I	SCALR	00E40 V	1
SLS1K	R	SCA R	00ED2 V	1	SLS1Y	R	ARRAY	003CC V	10	SLS1YT	R	SCALR	00F73 V	1
SLS1YC	R	SCA R	00F41 V	1	SLS1Z	R	ARRAY	003D6 V	10	SLS1ZT	R	SCALR	00F74 V	1
SLS1ZC	R	SCA R	00F42 V	1	SLS2K	R	SCALR	00ED3 V	1	SLS2Y	R	ARRAY	003E0 V	10
SLS2YT	R	SCA R	00F75 V	1	SLS2YO	R	SCALR	00F43 V	1	SLS2Z	R	ARRAY	003EA V	10
SLS2ZT	R	SCA R	00F76 V	1	SLS2ZO	R	SCALR	00F44 V	1	SLS3K	R	SCALR	00ED4 V	1
SLS3Y	R	ARR Y	003F4 V	10	SLS3YT	R	SCALR	00F77 V	1	SLS3YO	R	SCALR	00F45 V	1
SLS3Z	R	ARR Y	003FE V	10	SLS3ZT	R	SCALR	00F78 V	1	SLS3ZO	R	SCALR	00F46 V	1
SLTOF	I	SCA R	00E41 V	1	SLWAIT	I	SCALR	00E42 V	1	SLY	R	ARRAY	003B8 V	10
SLYT	R	SCA R	00F6F V	1	SLYO	R	SCALR	00F3D V	1	SLZ	R	ARRAY	003C2 V	10
SLZT	R	SCA R	00F70 V	1	SLZO	R	SCALR	00F3E V	1	SPEED	R	ARRAY	000B4 V	10
SQAC	R	SCA R	00E90 V	1	SQA1	R	SCALR	00E91 V	1	SQA2	R	SCALR	00E92 V	1
SQRT	R	SFR 0	INTRIN		SQ1C	R	SCALR	00E99 V	1	SQ11	R	SCALR	00E9A V	1
SQ12	R	SCA R	00E9B V	1	SQ20	R	SCALR	00EA2 V	1	SQ21	R	SCALR	00EA3 V	1
SQ22	R	SCA R	00EA4 V	1	SQ30	R	SCALR	00EAB V	1	SQ31	R	SCALR	00EAC V	1
SQ32	R	SCA R	00EAD V	1	SX	R	SCALR	00F5B V	1	T	R	SCALR	00000 L	1
TALM	R	SCA R	00F9C V	1	TDUMP	R	ARRAY	00E30 V	5	TEMP	R	SCALR	00F6E V	1
TF	R	SCA R	000C2 L	1	THSL	R	SCALR	00ED7 V	1	THSLA	R	SCALR	00EDB V	1
THSLOS	R	SCA R	00ED6 V	1	THSLS1	R	SCALR	00ED8 V	1	THSLS2	R	SCALR	00ED9 V	1
THSLS3	R	SCA R	00EDA V	1	TIME	R	ARRAY	000AA V	10	TIMEON	R	SCALR	00EF6 V	1
TIMTST	R	SCA R	00EDC V	1	TPHIDX	R	ARRAY	003AE V	10	TPULSE	R	SCALR	00EB3 V	1
TRS1	R	SCA R	00F8B V	1	TWODT	R	SCALR	00EFA V	1	TWOPI	R	SCALR	00EB2 V	1
THOZETC	R	ARR Y	00104 V	10	THOZETR	R	SCALR	00EB1 V	1	UMAY	R	SCALR	00F26 V	1
UMAZ	R	SCA R	00F27 V	1	UMBY	R	SCALR	00F24 V	1	UMBZ	R	SCALR	00F25 V	1
UMF	R	SCA R	00EC2 V	1	UMPY	R	SCALR	00F20 V	1	UMPZ	R	SCALR	00F21 V	1
UMT	R	SCA R	00EC3 V	1	UMTY	R	SCALR	00F22 V	1	UMTZ	R	SCALR	00F23 V	1
UM1Y	R	SCA R	00F28 V	1	UM1Z	R	SCALR	00F29 V	1	UM2Y	R	SCALR	00F2A V	1
UM2Z	R	SCA R	00F2B V	1	UM3Y	R	SCALR	00F2C V	1	UM3Z	R	SCALR	00F2D V	1
UP	R	SCA R	00049 L	1	UPP	R	SCALR	0004C L	1	UPT	R	SCALR	00059 L	1
UT	R	SCA R	00086 L	1	VMP	R	SCALR	00046 L	1	VMT	R	SCALR	000B3 L	1
WCL		SFR 0	EXTERN		WDAC		SPR00	EXTERN		WDW		SPR00	EXTERN	
X	R	SCA R	0001E L	1	XD	R	SCALR	00021 L	1	XDB	R	SCALR	00EB2 V	1
XCC	R	SCA R	00F90 V	1	XDDB	R	SCALR	00FAA V	1	XF1	R	SCALR	00EEA V	1
XIDCY	R	SCA R	00F35 V	1	XIDDYB	R	SCALR	00FA8 V	1	XIDDZ	R	SCALR	00F36 V	1
XIDCZB	R	SCA R	00FA9 V	1	XIDMAG	R	SCALR	00FA0 V	1	XIDY	R	SCALR	00030 L	1
XIDYB	R	SCA R	00EB0 V	1	XIDZ	R	SCALR	00031 L	1	XIDZB	R	SCALR	00EB1 V	1
XIDC	R	SCA R	00E70 V	1	XIY	R	SCALR	0002E L	1	XIZ	R	SCALR	0002F L	1
XMLN	R	SCA R	00E6E V	1	XSCALE	R	ARRAY	002CE V	64	XSLOW	R	SCALR	00EC9 V	1
XYTEMP	R	SCA R	00F9E V	1	XZTEMP	R	SCALR	00F9F V	1	Y	R	SCALR	0001F L	1
YC	R	SCA R	00022 L	1	YDB	R	SCALR	00EB3 V	1	YDD	R	SCALR	00F2E V	1
YCCB	R	SCA R	00FAB V	1	YSLOW	R	SCALR	00EF9 V	1	Z	R	SCALR	00020 L	1
ZC	R	SCA R	00023 L	1	ZDB	R	SCALR	00EB4 V	1	ZDD	R	SCALR	00F2F V	1
ZCCB	R	SCA R	00FAC V	1	ZERO	R	ARRAY	00000 V	32					

LABEL	HEX LOC	LABEL	HEX LOC	LABEL	HEX LOC	LABEL	HEX LOC	LABEL	HEX LOC	LABEL	HEX LOC
1	00AC3	10	00DF8	11	00E55	71	00029	72	00062	73	000C4
74	00CCC	75	00029	100	01570	200	014C6	201	0140A	202	013DD
203	013C7	204	013FE	205	013E9	213	013D7	215	013F6	300	0173E
600	015FA	601	0162A	700	016E8	701	017C5	703	0170D	707	01732
709	00E6C	710	00EE3	711	00178	712	00172	720	016FF	721	01724

750	00EAC	751	00EB2	752	00EB5	753	00ED8	754	00047	755	0003B
757	00C34	758	0013C	759	0015C	760	001A1	800	00202	801	00E3E
802	0000C	900	016D2	1004	0011D	1006	000FD	1100	00190	1101	00182
1102	00192	1200	01224	1201	01238	1300	00F34	1400	00801	1401	00AEA
1402	00AE2	1403	00AFD	1404	00B51	1405	00B7D	1410	0080F	1411	00B1A
1412	00B28	1413	00B47	2001	00031	2002	00146	2003	0020C	2150	01233
2601	00EE8	2603	00FC7	2621	0110A	2622	0114F	2623	01155	2656	0004F
9000	0176D										

LOCAL VARIABLE (4030 WORDS)!

0000C	ZERO	00020	DA1	00040	SF1	00060	IBIAS	000A0	GHMCBQ	000AA	TIME
000B4	SPEED	000BE	ETADD	000C8	ETADLB	000D2	ETADB	000DC	ETAB	000E6	ETADDBB
000FC	ETACB	000FA	ETABB	00104	THOZITC	0010E	DA1MAX	0012E	DA1MIN	0014E	DA1MXAVG
0016E	DA1MNVG	0018E	ICARD	002CE	XSCADE	003CE	DAC	003AE	SCALE	003BE	ICHNNL
003AE	TFMID	003B8	SLY	003C2	SLZ	003CC	SLS1Y	003D6	SLS1Z	003E0	SLS2Y
003EA	SLS2Z	003F4	SLS3Y	003FE	SLS3Y	00408	SLAY	00412	SLAZ	0041C	BUFFRA
0051C	BUFFR	00E1C	IOUT	00E26	AOUT	00E30	TDUMP	00E35	APUMP	00E38	ITAPE
00E39	ICARD	00E3A	IWAIT	00E3B	IBACJ	00E3C	IREMOD	00E3D	ITOF	00E3E	IGATHER
00E3F	SLGATER	00E40	SLRMOD	00E41	SLTOH	00E42	SLWAIT	00E43	SLCARD	00E44	SLBACK
00E45	KVWFT	00E46	KS3	00E47	LR	00E5B	KPY	00E5C	KPZ	00E5D	KTY
00E5E	KTZ	00E5F	KS1	00E60	KS2	00E61	KB	00E62	LB	00E63	M
00E64	I2	00E65	I1	00E66	KPPY	00E67	KPPZ	00E68	KPTY	00E69	KPTZ
00E6A	MTWFI	00E6B	IEXIT	00E6C	IIDUFP	00E6D	IIPULS	00E6E	IWORD	00E6F	XMUN
00E70	XIDC	00E71	MTAPE	00E72	ISLTIP	00E73	ITYPE	00E74	LPR	00E75	NMAX
00E76	IMAX	00E77	NCHAN	00E78	KCHAH	00E79	AKPYO	00E7A	AKPY1	00E7B	AKPY2
00E7C	AKPY3	00E7D	AKPZO	00E7E	AKPZ2	00E7F	AKPZ8	00E80	AKPZ3	00E81	AKTYO
00E82	AKTY1	00E83	AKTY2	00E84	ARTY5	00E85	AKTZO	00E86	ARTZ1	00E87	AKTZ2
00E88	AKTZ3	00E89	CPPY	00E8A	CPPZ	00E8B	CPTY	00E8C	CPTZ	00E8D	SKAO
00E8E	SKA1	00E8F	SKA2	00E90	SQAO	00E91	SQA1	00E92	SQA2	00E93	SCAO
00E94	SCA1	00E95	SCA2	00E96	SK10	00E97	SK11	00E98	SK12	00E99	SQ10
00E9A	SQ11	00E9B	SQ12	00E9C	SC1C	00E9D	SC11	00E9E	SC12	00E9F	SK20
00EA0	SK21	00EA1	SK22	00EA2	SQ20	00EA3	SQ21	00EA4	SQ22	00EA5	SC20
00EA6	SC21	00EA7	SC22	00EA8	SK30	00EA9	SK31	00EAA	SK32	00EAB	SQ30
00EAC	SQ31	00EAD	SQ32	00EAE	SC3C	00EAF	SC31	00EB0	SC32	00EB1	THOZETR
00EB2	THOFI	00EB3	TPULSE	00EB4	IBSEQBC	00EB5	BKPY	00EB6	BKPZ	00EB7	BKTY
00EB8	BKTZ	00EB9	QSPEED	00EBA	DES1P	00EBB	DES1Z	00EBC	FS1MAX	00EBD	ICAV
00EBE	RP	00EBF	RT	00EC0	ELP	00EC1	ELT	00EC2	UMP	00EC3	UMT
00EC4	FSFPY	00EC5	FSFPZ	00EC6	FSFTP	00EC7	FSFTZ	00EC8	DT2M18	00EC9	XSLOW
00ECA	EMAXP	00ECB	EMAXT	00ECC	ARPY5	00ECD	AKPZ4	00ECE	AKTY4	00ECF	AKTZ4
00ED0	ISIDE	00ED1	SLK	00ED2	SLS1J	00ED3	SLS2K	00ED4	SLS3K	00ED5	SLAK
00ED6	THSLO	00ED7	THSL	00ED8	THSLS1	00ED9	THSLS2	00EDA	THSLS3	00EDB	THSLA
00EDC	TIMTS	00EDD	DCRIST	00EDE	IDCTOT	00EDF	NUMLINES	00EE0	FCAPPY	00EE1	FCAPPZ
00EE2	FCAPT	00EE3	FCAPTZ	00EE4	KPUMO	00EE5	J	00EE6	I	00EE7	JREMOD
00EE8	RUNID	00EE9	K	00EEA	XF1	00EEB	CM	00EEC	GAMO	00EED	GAM1
00EEE	NUPRU	00EEF	KGPASS	00EF0	MAXGPASS	00EF1	JNTR	00EF2	IMAXIO	00EF3	KDUMP
00EF4	KTAPE	00EF5	IDUMP	00EF6	TIMEMN	00EF7	L	00EF8	IFILE	00EF9	YSLOW
00EFA	THOCT	00EFB	C1P	00EFC	C1T	00EFD	C3P	00EFE	C3T	00EFF	C2P
00F00	C2T	00F01	ELOD2P	00F02	ELOD3T	00F03	CLP	00F04	CLT	00F05	ICL
00F06	MOCR	00F07	JNTC	00F08	BETA	00F09	GAO	00F0A	GA1	00F0B	GA2
00F0C	GA3	00F0D	GA4	00F0E	AKPPP	00F0F	AKPPZ	00F10	AKPTY	00F11	AKPTZ
00F12	CPY	00F13	CPZ	00F14	CTY	00F15	CTZ	00F16	AKBO	00F17	AKB1

```
CCF18 AKB2      CCF19 ACBO      00F1A ACB1      00F1B ACB2      00F1C CPDBY     00F1D CPDBZ
CCF1E CIDBY     OCF1F CIDBZ     OCF20 UMPY      00F21 UMPZ      0CF22 UMTY      00F23 UMTZ
CCF24 LMBY      OCF25 UMBZ      00F26 UMAY      00F27 UMAZ      00F28 UM1Y      00F29 UM1Z
CCF2A LM2Y      CCF2B UM2Z      OCF2C UM3Y      00F2D UM3Z      0CF2E YDD       00F2F ZDD
CCF30 PHIDD     CCF31 PHIDX     OOF32 PHIX      00F33 PHIDDY    00F34 PHIDDZ    00F35 XIDDY
CCF36 XIDDZ     OCF37 AKPDBY    OCF38 AKPDKZ    00F39 AKTDBY    0CF3A AKTDBZ    00F3B ABF
CCF3C ELAPT ME  CCF3D SLYO      OCF3E SLZC      00F3F SLAYO     00F40 SLAZO     00F41 SLS1YO
CCF42 SLS1Z     OCF43 SLS2YO    00F44 SLS2YO    00F45 SLS3YO    00F46 SLS3ZO    00F47 IPASS
CCF48 NPASS     CCF49 KTEMP     OOF4A PHIDZSQ   00F4B PHIDXA    00F4C AKPY      00F4D AKPZ
CCF4E AKYY      OCF4F AKTZ      OCF50 CB        00F51 KSA       0CF52 BSA       00F53 CSA
CCF54 GS1       CCF55 CS1       00F56 Q82       00F57 CS2       00F58 BS3       00F59 CS3
CCF5A GA        OCF5B SX        00F5C CX        00F5D FUPY      00F5E FUTY      00F5F FUBY
CCF6C FUAY      CCF61 FUS1Y     00F62 FUS2P     00F63 FUS3Y     00F64 FUPZ      00F65 FUTZ
CCF66 FUBZ      OCF67 FUAZ      00F68 FUS1Y     00F69 FUS2Z     0CF6A FUS3Z     00F6B PSFP
CCF6C FSFT      OCF6D IF1       COF6E TEMP      00F6F SLYT      00F70 SLZT      00F71 SLAYT
CCF72 SLAZT     CCF73 SLS1YT    00F74 SLS1VT    00F75 SLS2YT    0CF76 SLS2ZT    00F77 SLS3YT
CCF78 SLS3Z     OCF79 FFY       00F7A FPZ       00F7B FTY       00F7C FTZ       00F7D PP
CCF7E FT        CCF7F FBX       0CF80 FBY       00F81 FBZ       0CF82 FAY       00F83 FAZ
CCF84 FS1Y      CCF85 FS2Y      OCF86 FS3Y      00F87 FS1Z      00F88 FS2Z      00F89 FS3Z
CCF8A RS1       CCF8B IRS1      00F8C DKS100    00F8D FRPY      0CF8E FRTY      00F8F FRBY
CCF9C FRAY      CCF91 FRS1Y     00F92 FRS2P     00F93 FRPZ      00F94 FRTZ      00F95 FRBZ
CCF96 FRAZ      CCF97 FRS1Z     00F98 FRS2Y     00F99 FRS3Y     0CF9A FRS3Z     00F9B DSPEED
CCF9C TALP      CCF9D XDD       OCF9E XYTEMP    00F9F XZTEMP    00FA0 XIDMAG    00FA1 A1
CCFA2 A2        OCFA3 A3        OCFA4 A4        00FA5 A5        00FA6 A6        00FA7 A7
CCFA8 XIDDY     OCFA9 XIDDZB    00FAA XDDB      00FAB YDDB      00PAC ZDDB      00FAD PHIDDXB
CCFAE PHIDD B   CCFAF PHIDDZB   OCFB0 XIDYK     00FB1 XIDZB     0CFB2 XDB       00FB3 YDB
CCFB4 ZCB       OCFB5 PHIDXB    00FB6 PHIDPB    00FB7 PHIDZB    00FB8 DELS1     00FB9 DELS2
CCFBA CELS3     OCFBB IFULSE    00FBC RPULSE    00FBD REM
```

```
FLANK COMMON (  WORCS)

LABELEC COMMON BLOCK /DATAJB/ (7 WORDS)I

CCCCC CL        00001 C1        00002 C2        00003 C3        00004 ELBDE     00005 PI2
COCC6 EMAX

LABELEC COMMON BLOCK /T/ (5 WORDS)I

CCCCC T         0  01 DT        C0002 TF        00003 DTA2      00004 DT204

LABELEC COMMON BLOCK /BENDIN/ (1962 WORDS))

CCCCC PHIR      0003C FEER      00078 PHIC      00348 PSICBX    00352 FEEC      00622 MODC
CC623 IRF       OC624 IRT       00625 IRA       00626 IRB       00627 IRS1      00628 IRS2
CC629 IRS3      CC62A ICB       0062B ICA       0062C ICP       0062D ICT       0062E ICS1
CC62F ICS2      CC63C ICS3      00631 PHICKX    0063B PHICBY    00645 PHICBZ    0064F PSICAX
CC659 PHICP     CC663 PHICPZ    0066D PHICAY    0C677 PHICTZ    00681 PHICAY    0068B PHICAZ
CC695 PHICS Y   CC69F PHICS1Z   006A9 PHICS2Y   006B3 PHICS2Z   006BD PHICS3Y   006C7 PHICS3Z
CC6D1 PHIRP     OC6D2 PHIRT     006D3 PHIRI     006D4 PHIRB     006D5 PHIRS1    006D6 PHIRS2
CC6D7 PHIRS     CC6D8 AC1       006E2 AC2       006EC AC3       006F6 AC4       00700 AC5
```

```
CC7CA AC6        C0714 AC7       0071E CAC1      00721 CAC2      00724 CAC9      00727 CAC4
CC72A CAC8       CC72D CAC6      00730 CAC7      00733 DAC1      00736 DAC2      00739 DAC3
CC73C CAC4       0C73F DAC5      00742 DAC6      00745 DAC7      00748 JAC1      00749 JAC2
CC7AA JAC3       0C74B JAC4      0074C JAC5      0074D JAC6      0074E JAC7      0074F OHMC
CC7E9 R          CC76C AMR       0077C AIR1      0078B AIR2      0079A AIR3      007A9 OHMR
CC7AA OHMRS
```

LABELED COMMON BLOCK /DELTIN/ (96 WORDS):

```
CCCCC DELPY      0C001 DELPZ     CCC02 DELTP     000C3 DELTZ     00004 DELAY     00005 DELAZ
CCCC6 DELPX      CCC07 DELS1Y    CCC08 DELS3Y    00009 DELS3Y    0000A DELS1Z    0000B DELS2Z
CCCCC DELS3      0C00D DELP      C000E DELT      000CF DELA      00010 DMIN      00011 DELDPY
CCC12 DELDP      CC013 DELDTY    00C14 DELDAZ    00015 DELDBX    00016 DELDAY    00017 DELDAZ
CCC18 DELDS Y    CC019 DELDS2Y   COC1A DELDS3Y   0001B DELDS1Z   0001C DELDS2Z   0001D DELDS3Z
CCC1E X          CCC1F Y         00C20 Z         00021 XD        00022 YD        00023 ZD
CCC24 LP         CC025 LT        00026 LA        00027 LS1       00028 LS2       00029 LS3
CCC2A PHIZ       C002B PHIY      0002C PHIDY     0002D PHIDY     0002E XIY       0002E XIZ
CCC3C XIDY       00031 XIDZ      00032 ETA       0003C ETAD      00046 VWP       00047 GPP
CCC48 GP         0C049 UP        000AA DELPOY    0004B DELPPZ    0004C UPP       0004D DPPPY
CCC4E DPPPZ      0004F DELDPPY   00C50 DELDPPZ   00051 DDPPPY    00052 DDPPPZ    00053 VWT
CCC54 GPT        0OC55 QT        00056 UT        00057 DELPTY    00058 DELPTZ    00059 UPT
CCCEA DPPTY      00058 DPPTZ     0C05C DELDOTY   0005D DELDPTZ   0005E DDPPTY    0005F DDPPTZ
```

INTRINSIC SUBPROGRAMS USED:

```
ABS       OS       SIGN       SIN       SQRT
```

EXTERNAL SUBPROGRAMS REQUIRED:

```
BENDING   UFFOUT   DELTAS    EXIT       GOUR1     JOUR2      BSL      WCL
WDAC      DW       FI105     FI106      WI108     MID0       MI0C     98CDRDEE
9BCDREAD  BCDWRIT  9COS      9ENDFILE   9ENDIOL   9INITIAL   9INPUT   9IODATA
9IOIUSA   IT3R     9PRINT    9REWIND    9RT0I     9SIN       9SQRT    9STOP
```

HIGHEST ERROR SEVERITY: 0 (NO ERRORS)

```
                     DEC       HEX
                     WORDS     WORDS
                     -----     -----
 GENERATED CODE :    8216      C2018
       CONSTANT :      15      C000F
 LOCAL VARIABLE :    4C30      C0FBE
           TEMP :      17      C0011
                     -----     -----
  TOTAL PROGRAM :   12278      C2FF6    (PLUS LABELED COMMON)
```

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```
      SUBROUTINE DELTAS
C
      COMMON /DELTIN/ DELPY,DELPZ,DELTY,DELTZ,DELAY,DELAZ,DELBX,DELS1Y
     * ,DELS2Y,DELS3Y,DELS1Z,DELS2Z,DELS3Z,DELP,DELT,DELA,DMIN,DELDPY
     * ,DELDPZ,DELDTY,DELDTZ,DELDBX,DELDAY,DELDAZ,DELDS1Y,DELDS2Y
     * ,DELDS3Y,DELDS1Z,DELDS2Z,DELDS3Z, X,Y,Z,XD,YD,ZD,LP,LT,LA,LS1
     * ,LS2,LS3,PHIZ,PHIY,PHIDZ,PHIDY,XIY,XIZ,XIDY,XIDZ,ETA(10),ETAD(10)
     * ,VBP,QPP,GP,UE,DELPPY,DELPPZ,CPP,DPPPY,DPPPZ,DELDPPY,DELDPPZ
     * ,DDPPPY,DDPPPZ,VHT,QPT,QT,UT,DELPTY,DELPTZ,UPT,DPPTY,DPPTZ
     * ,DELDPTY,DELDPTZ,DDPPTY,DDPPTY
      COMMON /BENDIN/ PHIR(3,20,1),FTER(3,20,1),PHIC(3,24,10),PSICBX(10)
     *,FEEC(3,24,10),MOCC,IRP,IRT,IRI,IRB,IRS1,IRS2,IRS3,ICB,ICA,ICP,ICT
     *,ICS1,ICS2,ICS3,PHICBX(10),PHIMBY(10),PHICBZ(10),PSICAX(10)
     *,PHICPY(10),PHICPZ(10),PHICTY(20),PHICTZ(10),PHICAY(10),PHICAZ(10)
     *,PHICS1Y(10),PHICS1Z(10),PHICS2Y(10),PHICS2Z(10),PHICS3Y(10)
     *,PHICS3Z(10),PHIRP,PHIRT,PHIRA,PHIRB,PHIRS1,PHIRS2,PHIRS3
     *,AC1(10),AC2(10),AC3(10),AC4(11),AC5(10),AC6(10),AC7(10)
     *,CAC1(3),CAC2(3),CAC3(3),CAC4(4),CAC5(3),CAC6(3),CAC7(3)
     *,DAC1(3),DAC2(3),DAC3(3),DAC4(4),DAC5(3),DAC6(3),DAC7(3)
     *,JAC1,JAC2,JAC3,JAC4,JAC5,JAC6,JAC7
     *,OHMC(10),R(20),AMR(15),AIR1(10),AIR2(10),AIR3(15),OHMR,OHMRSB
      REAL LP,LA,LT,LS1,LS2,LS3, LB
C
C
      DELPY= Y+LP*PHIZ+PHIRP*XIY
     *+PHICPY(1)*ETA(1)+PHICPY(2)*ETA(2)+PHICPY(3)*ETA(3)
     *+PHICPY(4)*ETA(4)+PHICPY(5)*ETA(5)+PHICPY(6)*ETA(6)
     *+PHICPY(7)*ETA(7)+PHICPY(8)*ETA(8)+PHICPY(9)*ETA(9)
     *+PHICPY(10)*ETA(10)
      DELPZ= Z-LP*PHIY+PHIRP*XIZ
     *+PHICPZ(1)*ETA(1)+PHICPZ(2)*ETA(2)+PHICPZ(3)*ETA(3)
     *+PHICPZ(4)*ETA(4)+PHICPZ(5)*ETA(5)+PHICPZ(6)*ETA(6)
     *+PHICPZ(7)*ETA(7)+PHICPZ(8)*ETA(8)+PHICPZ(9)*ETA(9)
     *+PHICPZ(10)*ETA(10)
      DELTY= Y+LT*PHIZ+PHIRT*XIY
     *+PHICTY(1)*ETA(1)+PHICTY(2)*ETA(2)+PHICTY(3)*ETA(3)
     *+PHICTY(4)*ETA(4)+PHICTY(5)*ETA(5)+PHICTY(6)*ETA(6)
     *+PHICTY(7)*ETA(7)+PHICTY(8)*ETA(8)+PHICTY(9)*ETA(9)
     *+PHICTY(10)*ETA(10)
      DELTZ= Z-LT*PHIY+PHIRT*XIZ
     *+PHICTZ(1)*ETA(1)+PHICTZ(2)*ETA(2)+PHICTZ(3)*ETA(3)
     *+PHICTZ(4)*ETA(4)+PHICTZ(5)*ETA(5)+PHICTZ(6)*ETA(6)
     *+PHICTZ(7)*ETA(7)+PHICTZ(8)*ETA(8)+PHICTZ(9)*ETA(9)
     *+PHICTZ(10)*ETA(10)
      DELAY= Y+LA*PHIZ+PHIRA*XIY
     *+PHICAY(1)*ETA(1)+PHICAY(2)*ETA(2)+PHICAY(3)*ETA(3)
     *+PHICAY(4)*ETA(4)+PHICAY(5)*ETA(5)+PHICAY(6)*ETA(6)
     *+PHICAY(7)*ETA(7)+PHICAY(8)*ETA(8)+PHICAY(9)*ETA(9)
     *+PHICAY(10)*ETA(10)
      DELAZ= Z-LA*PHIY+PHIRA*XIZ
     *+PHICAZ(1)*ETA(1)+PHICAZ(2)*ETA(2)+PHICAZ(3)*ETA(3)
     *+PHICAZ(4)*ETA(4)+PHICAZ(5)*ETA(5)+PHICAZ(6)*ETA(6)
     *+PHICAZ(7)*ETA(7)+PHICAZ(8)*ETA(8)+PHICAZ(9)*ETA(9)
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```
      *-PHICAZ(10)*ETA(10)                                         373
      DELBX= X                                                     374
      *-PHICBX(1)*ETA(1)-PHICBX(2)*ETI(2)-PHICBX(3)*ETA(3)         375
      *-PHICBX(4)*ETA(4)-PHICBX(5)*ETI(5)-PHICBX(6)*ETA(6)         376
      *-PHICBX(7)*ETA(7)-PHICBX(8)*ETI(8)-PHICBX(9)*ETA(9)         377
      *-PHICBX(10)*ETA(10)                                         378
      DELS1Y= Y+LS1*PHIZ+PHIRS1*XIY                                379
      *-PHICS1Y(1)*ETA(1)-PHICS1Y(2)*TTA(2)-PHICS1Y(3)*ETA(3)      380
      *-PHICS1Y(4)*ETA(4)-PHICS1Y(5)*TTA(5)-PHICS1Y(6)*ETA(6)      381
      *-PHICS1Y(7)*ETA(7)-PHICS1Y(8)*TTA(8)-PHICS1Y(9)*ETA(9)      382
      *-PHICS1Y(10)*ETA(10)                                        383
      DELS2Y= Y+LS2*PHIZ+PHIRS2*XIY                                384
      *-PHICS2Y(1)*ETA(1)-PHICS2Y(2)*TTA(2)-PHICS2Y(3)*ETA(3)      385
      *-PHICS2Y(4)*ETA(4)-PHICS2Y(5)*TTA(5)-PHICS2Y(6)*ETA(6)      386
      *-PHICS2Y(7)*ETA(7)-PHICS2Y(8)*TTA(8)-PHICSPY(9)*ETA(9)      387
      *-PHICS2Y(10)*ETA(10)                                        388
C
C     THIS SEAL IS NOT IN FUEL PUMP
      DELS3Y= Y+LS3*PHIZ+PHIRS3*XIY
      *-PHICS3Y(1)*ETA(1)-PHICS3Y(2)*TTA(2)-PHICS3Y(3)*ETA(3)      390
      *-PHICS3Y(4)*ETA(4)-PHICS3Y(5)*TTA(5)-PHICS3Y(6)*ETA(6)      391
      *-PHICS3Y(7)*ETA(7)-PHICS3Y(8)*TTA(8)-PHICS3Y(9)*ETA(9)      392
      *-PHICS3Y(10)*ETA(10)                                        393
C
      DELS1Z= Z-LS1*PHIY+PHIRS1*XIZ                                394
      *-PHICS1Z(1)*ETA(1)-PHICS1Z(2)*TTA(2)-PHICS1Z(3)*ETA(3)      395
      *-PHICS1Z(4)*ETA(4)-PHICS1Z(5)*TTA(5)-PHICS1Z(6)*ETA(6)      396
      *-PHICS1Z(7)*ETA(7)-PHICS1Z(8)*TTA(8)-PHICS1Z(9)*ETA(9)      397
      *-PHICS1Z(10)*ETA(10)                                        398
      DELS2Z= Z-LS2*PHIY+PHIRS2*XIZ                                399
      *-PHICS2Z(1)*ETA(1)-PHICS2Z(2)*TTA(2)-PHICS2Z(3)*ETA(3)      400
      *-PHICS2Z(4)*ETA(4)-PHICS2Z(5)*TTA(5)-PHICS2Z(6)*ETA(6)      401
      *-PHICS2Z(7)*ETA(7)-PHICS2Z(8)*TTA(8)-PHICS2Z(9)*ETA(9)      402
      *-PHICS2Z(10)*ETA(10)                                        403
C
C     THIS SEAL IS NOT IN FUEL PUMP
      DELS3Z=Z-LS3*PHIY+PHIRS3*XIZ                                 404
      *-PHICS3Z(1)*ETA(1)-PHICS3Z(2)*TTA(2)-PHICS3Z(3)*ETA(3)      405
      *-PHICS3Z(4)*ETA(4)-PHICS3Z(5)*TTA(5)-PHICS3Z(6)*ETA(6)      406
      *-PHICS3Z(7)*ETA(7)-PHICS3Z(8)*TTA(8)-PHICS3Z(9)*ETA(9)      407
      *-PHICS3Z(10)*ETA(10)                                        408
C
      DELP= SQRT(DELPY*DELPY+DELPZ*DTLPZ)                          409
      DELT= SQRT(DELTY*DELTY+DELTZ*DTLTZ)                          410
      DELA= SQRT(DELAY*DELAY+DELAZ*DTLAZ)                          411
      IF(DELP.LT.DMIN) DELP= DMIN                                  412
      IF(DELT.LT.DMIN) DELT= DMIN                                  413
      DELDPY= YD+LP*PHICZ+PHIRP*XIDY                               414
      *-PHICPY(1)*ETAD(1)-PHICPY(2)*EAAD(2)-PHICPY(3)*ETAD(3)      415
      *-PHICPY(4)*ETAD(4)-PHICPY(5)*EAAD(5)-PHICPY(6)*ETAD(6)      416
      *-PHICPY(7)*ETAD(7)-PHICPY(8)*EAAD(8)-PHICPY(9)*ETAD(9)      417
      *-PHICPY(10)*ETAD(10)                                        418
      DELDPZ= ZD-LP*PHICY+PHIRP*XIDZ                               419
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```
     *-PHICPZ(1)*ETAD(1)-PHICPZ(2)*EAAD(2)-PHICPZ(3)*ETAD(3)
     *-PHICPZ(4)*ETAD(4)-PHICPZ(5)*EAAD(5)-PHICPZ(6)*ETAD(6)
     *-PHICPZ(7)*ETAD(7)-PHICPZ(8)*EAAD(8)-PHICPZ(9)*ETAD(9)
     *-PHICPZ(10)*ETAD(10)
      DELCTY= YD+LT*PHIDZ+PHIRT*XIDY
     *-PHICTY(1)*ETAD(1)-PHICTY(2)*EAAD(2)-PHICTY(3)*ETAD(3)
     *-PHICTY(4)*ETAD(4)-PHICTY(5)*EAAD(5)-PHICTY(6)*ETAD(6)
     *-PHICTY(7)*ETAD(7)-PHICTY(8)*EAAD(8)-PHICTY(9)*ETAD(9)
     *-PHICTY(10)*ETAD(10)
      DELCTZ= ZD-LT*PHIDY+PHIRT*XIDZ
     *-PHICTZ(1)*ETAD(1)-PHICTZ(2)*EAAD(2)-PHICTZ(3)*ETAD(3)
     *-PHICTZ(4)*ETAD(4)-PHICTZ(5)*EAAD(5)-PHICTZ(6)*ETAD(6)
     *-PHICTZ(7)*ETAD(7)-PHICTZ(8)*EAAD(8)-PHICTZ(9)*ETAD(9)
     *-PHICTZ(10)*ETAD(10)
      DELCBX= XD
     *-PHICBX(1)*ETAD(1)-PHICBX(2)*EAAD(2)-PHICBX(3)*ETAD(3)
     *-PHICBX(4)*ETAD(4)-PHICBX(5)*EAAD(5)-PHICBX(6)*ETAD(6)
     *-PHICBX(7)*ETAD(7)-PHICBX(8)*EAAD(8)-PHICBX(9)*ETAD(9)
     *-PHICBX(10)*ETAD(10)
      DELDAY= YD+LA*PHIDZ+PHIRA*XIDY
     *-PHICAY(1)*ETAD(1)-PHICAY(2)*EAAD(2)-PHICAY(3)*ETAD(3)
     *-PHICAY(4)*ETAD(4)-PHICAY(5)*EAAD(5)-PHICAY(6)*ETAD(6)
     *-PHICAY(7)*ETAD(7)-PHICAY(8)*EAAD(8)-PHICAY(9)*ETAD(9)
     *-PHICAY(10)*ETAD(10)
      DELDAZ= ZD-LA*PHIDY+PHIRA*XIDZ
     *-PHICAZ(1)*ETAD(1)-PHICAZ(2)*EAAD(2)-PHICAZ(3)*ETAD(3)
     *-PHICAZ(4)*ETAD(4)-PHICAZ(5)*EAAD(5)-PHICAZ(6)*ETAD(6)
     *-PHICAZ(7)*ETAD(7)-PHICAZ(8)*EAAD(8)-PHICAZ(9)*ETAD(9)
     *-PHICAZ(10)*ETAD(10)
      DELDS1Y= YD+LS1*PHIDZ+PHIRS1*XSDY
     *-PHICS1Y(1)*ETAD(1)-PHICS1Y(2)*ETAD(2)-PHICS1Y(3)*ETAD(3)
     *-PHICS1Y(4)*ETAD(4)-PHICS1Y(5)*ETAD(5)-PHICS1Y(6)*ETAD(6)
     *-PHICS1Y(7)*ETAD(7)-PHICS1Y(8)*ETAD(8)-PHICS1Y(9)*ETAD(9)
     *-PHICS1Y(10)*ETAD(10)
      DELDS2Y= YD+LS2*PHIDZ+PHIRS2*XSDY
     *-PHICS2Y(1)*ETAD(1)-PHICS2Y(2)*ETAD(2)-PHICS2Y(3)*ETAD(3)
     *-PHICS2Y(4)*ETAD(4)-PHICS2Y(5)*ETAD(5)-PHICS2Y(6)*ETAD(6)
     *-PHICS2Y(7)*ETAD(7)-PHICS2Y(8)*ETAD(8)-PHICS2Y(9)*ETAD(9)
     *-PHICS2Y(10)*ETAD(10)
      DELDS3Y= YD+LS3*PHIDZ+PHIRS3*XSDY
     *-PHICS3Y(1)*ETAD(1)-PHICS3Y(2)*ETAD(2)-PHICS3Y(3)*ETAD(3)
     *-PHICS3Y(4)*ETAD(4)-PHICS3Y(5)*ETAD(5)-PHICS3Y(6)*ETAD(6)
     *-PHICS3Y(7)*ETAD(7)-PHICS3Y(8)*ETAD(8)-PHICS3Y(9)*ETAD(9)
     *-PHICS3Y(10)*ETAD(10)
      DELDS1Z= ZD-LS1*PHIDY+PHIRS1*XSDZ
     *-PHICS1Z(1)*ETAD(1)-PHICS1Z(2)*ETAD(2)-PHICS1Z(3)*ETAD(3)
     *-PHICS1Z(4)*ETAD(4)-PHICS1Z(5)*ETAD(5)-PHICS1Z(6)*ETAD(6)
     *-PHICS1Z(7)*ETAD(7)-PHICS1Z(8)*ETAD(8)-PHICS1Z(9)*ETAD(9)
     *-PHICS1Z(10)*ETAD(10)
      DELDS2Z= ZD-LS2*PHIDY+PHIRS2*XSDZ
     *-PHICS2Z(1)*ETAD(1)-PHICS2Z(2)*ETAD(2)-PHICS2Z(3)*ETAD(3)
     *-PHICS2Z(4)*ETAD(4)-PHICS2Z(5)*ETAD(5)-PHICS2Z(6)*ETAD(6)
     *-PHICS2Z(7)*ETAD(7)-PHICS2Z(8)*ETAD(8)-PHICS2Z(9)*ETAD(9)
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      *-PHICS2Z(10)*ETAD(10)                                          473
C
C     THIS SEAL IS NOT IN FUEL PUMP
      DELDS3Z= 2D*LS3*PHICY*PHIRS3*XSDZ                               474
     *-PHICS3Z(1)*ETAD(1)-PHICS3Z(2)*ETAD(2)-PHICS3Z(3)*ETAD(3)       475
     *-PHICS3Z(4)*ETAD(4)-PHICS3Z(5)*ETAD(5)-PHICS3Z(6)*ETAD(6)       476
     *-PHICS3Z(7)*ETAD(7)-PHICS3Z(8)*ETAD(8)-PHICS3Z(9)*ETAD(9)       477
     *-PHICS3Z(10)*ETAD(10)                                           478
C
      VHP= (-DELDPY*DELPZ+DELDPZ*DELPY)/(DELP*DELP)                   479
      VHT= (-DELDTY*DELTZ+DELDTZ*DELTY)/(DELT*DELT)                   480
      IF(DELP.GT.GPP)                                                 481
     * UP=(GPP-GP)/DELP                                               482
     */DELPPY=UP*DELPY                                                483
     */DELPPZ=UP*DELPZ                                                484
     */UPP=(DELP-GPP)/DELP                                            485
     */DPPPY=UPP*DELPY                                                486
     */DPPPZ=UPP*DELPZ                                                487
     */DELDPPY=-UP*VHP*DELPZ                                          488
     */DELDPPZ= UP*VHP*DELPY                                          489
     */DDPPPY=DELDPY+GPP*VHP*DELPZ/DTLP                               490
     */DDPPPZ=DELDPZ-GPP*VHP*DELPY/DTLP                               491
     */GO TO 500                                                      492
      DPPPY=0.                                                        493
      DPPPZ=0.                                                        494
      DDPPPY=0.                                                       495
      DDPPPZ=0.                                                       496
      IF(DELP.GT.GP)                                                  497
     * UP=(DELP-GP)/DELP                                              498
     */DELPPY=UP*DELPY                                                499
     */DELPPZ=UP*DELPZ                                                500
     */DELDPPY=DELDPY+GP*VHP*DELPZ/DTLP                               501
      /DELDPPZ=DELDPZ-GP*VHP*DELPY/DTLP                               502
     */GO TO 500                                                      503
      DELPPY=0.                                                       504
      DELPPZ=0.                                                       505
      DELDPPY=0.                                                      506
      DELDPPZ=0.                                                      507
  500 CONTINUE                                                        508
      IF(DELT.GT.GPT)                                                 509
     * UT=(GPT-GT)/DELT                                               510
     */DELPTY=UT*DELTY                                                511
     */DELPTZ=UT*DELTZ                                                512
     */UPT=(DELT-GPT)/DELT                                            513
     */DPPTY=UPT*DELTY                                                514
     */DPPTZ=UPT*DELTZ                                                515
     */DELDPTY=-UT*VHT*DELTZ                                          516
     */DELDPTZ= UT*VHT*DELTY                                          517
     */DDPPTY=DELDTY+GPT*VHT*DELTZ/DTLT                               518
     */DDPPTZ=DELDTZ-GPT*VHT*DELTY/DTLT                               519
     */GO TO 501                                                      520
      DPPTY=0.                                                        521
      DPPTZ=0.                                                        522
```

```
      DDFPTY=0.
      DDFPTZ=0.
      IF(DELT.GT.GT)
     * UT=(DELT-GT)/DELT
     *,DELPTY=UT*DELTY
     *,DELPTZ=UT*DELTZ
     *,DELDPTY=DELDTY+GT*VWT*DELTZ/DELT
     *,DELDPTZ=DELDTZ-GT*VWT*DELTY/DELT
     *,GO TO 501
      DELPTY=0.
      DELPTZ=0.
      DELDPTY=0.
      DELDPTZ=0.
  501 CONTINUE
C
C
      RETURN
      END
```

NAME	TYPE	CLASS	HEX LOC	DEC WORDS	NAME	TYPE	CLASS	HEX LOC	DEC WORDS	NAME	TYPE	CLASS	HEX LOC	DEC WORDS
AC1	R	ARRAY	006D8 L	10	AC2	R	ARRAY	006E2 L	10	AC3	R	ARRAY	006EC L	10
AC4	R	ARRAY	006F6 L	10	AC5	R	ARRAY	00700 L	10	AC6	R	ARRAY	0070A L	10
AC7	R	ARRAY	00714 L	10	AIR1	R	ARRAY	0077C L	15	AIR2	R	ARRAY	0078B L	15
AIR3	R	ARRAY	0079A L	15	AMR	R	ARRAY	0076D L	15	CAC1	R	ARRAY	0071E L	3
CAC2	R	ARRAY	00721 L	3	CAC3	R	ARRAY	00724 L	3	CAC4	R	ARRAY	00727 L	3
CAC5	R	ARRAY	0072A L	3	CAC6	R	ARRAY	0072D L	3	CAC7	R	ARRAY	00730 L	3
DAC1	R	ARRAY	00733 L	3	DAC2	R	ARRAY	00736 L	3	DAC3	R	ARRAY	00739 L	3
DAC4	R	ARRAY	0073C L	3	DAC5	R	ARRAY	0073F L	3	DAC6	R	ARRAY	00742 L	3
DAC7	R	ARRAY	00745 L	3	DDPPPY	R	SCALR	00051 L	1	DDPPPZ	R	SCALR	00052 L	1
DDPPTY	R	SCALR	0005E L	1	DDPPTZ	R	SCALR	0005F L	1	DELA	R	SCALR	0000F L	1
DELAY	R	SCALR	00004 L	1	DELAZ	R	SCALR	00005 L	1	DELBX	R	SCALR	00006 L	1
DELDAY	R	SCALR	00016 L	1	DELDAZ	R	SCALR	00017 L	1	DELDBX	R	SCALR	00015 L	1
DELDPPY	R	SCALR	0004F L	1	DELDPPZ	R	SCALR	00050 L	1	DELDPTY	R	SCALR	0005C L	1
DELDPTZ	R	SCALR	0005D L	1	DELDPY	R	SCALR	00011 L	1	DELDPZ	R	SCALR	00012 L	1
DELDS1Y	R	SCALR	00018 L	1	DELDS1Z	R	SCALR	0001B L	1	DELDS2Y	R	SCALR	00019 L	1
DELDS2Z	R	SCALR	0001C L	1	DELDS3Y	R	SCALR	0001A L	1	DELDS3Z	R	SCALR	0001D L	1
DELDTY	R	SCALR	00013 L	1	DELDTZ	R	SCALR	00014 L	1	DELP	R	SCALR	0000D L	1
DELPPY	R	SCALR	0004A L	1	DELPPZ	R	SCALR	0004B L	1	DELPTY	R	SCALR	00057 L	1
DELPTZ	R	SCALR	00058 L	1	DELPY	R	SCALR	00000 L	1	DELPZ	R	SCALR	00001 L	1
DELS1Y	R	SCALR	00007 L	1	DELS1Z	R	SCALR	0000A L	1	DELS2Y	R	SCALR	00008 L	1
DELS2Z	R	SCALR	0000B L	1	DELS3Y	R	SCALR	00009 L	1	DELS3Z	R	SCALR	0000C L	1
DELT	R	SCALR	0000E L	1	DELTAB		BPROG	00000 P		DELTAS	R	SCALR	00000 V	1
DELTY	R	SCALR	00002 L	1	DELTZ	R	SCALR	00003 L	1	DMIN	R	SCALR	00010 L	1
DPPPY	R	SCALR	0004D L	1	DPPPZ	R	SCALR	0004E L	1	DPPTY	R	SCALR	0005A L	1
DPPTZ	R	SCALR	0005B L	1	ETA	R	ARRAY	00032 L	10	ETAD	R	ARRAY	0003C L	10
FEEC	R	ARRAY	00352 L	720	FEER	R	ARRAY	0003C L	60	GP	R	SCALR	00048 L	1
GPP	R	SCALR	00047 L	1	GPT	R	SCALR	00054 L	1	GT	R	SCALR	00055 L	1
ICA	I	SCALR	0062B L	1	ICB	I	SCALR	0062A L	1	ICP	I	SCALR	0062C L	1
ICS1	I	SCALR	0062E L	1	ICS2	I	SCALR	0062F L	1	ICS3	I	SCALR	00630 L	1
ICT	I	SCALR	0062D L	1	IRA	I	SCALR	00625 L	1	IRB	I	SCALR	00626 L	1
IRP	I	SCALR	00623 L	1	IRS1	I	SCALR	00627 L	1	IRS2	I	SCALR	00628 L	1
IRS3	I	SCALR	00629 L	1	IRT	I	SCALR	00624 L	1	JAC1	I	SCALR	00748 L	1
JAC2	I	SCALR	00749 L	1	JAC3	I	SCALR	0074A L	1	JAC4	I	SCALR	0074B L	1
JAC5	I	SCALR	0074C L	1	JAC6	I	SCALR	0074D L	1	JAC7	I	SCALR	0074E L	1
LA	R	SCALR	00026 L	1	LP	R	SCALR	00024 L	1	LS1	R	SCALR	00027 L	1
LS2	R	SCALR	00028 L	1	LS3	R	SCALR	00029 L	1	LT	R	SCALR	00025 L	1
NOCC	I	SCALR	00622 L	1	OHMC	R	ARRAY	0074F L	10	OHMR	R	SCALR	007A9 L	1
OHMRSC	R	SCALR	007AA L	1	PHIC	R	ARRAY	00078 L	720	PHICAY	R	ARRAY	00681 L	10
PHICAZ	R	ARRAY	0068B L	10	PHICBX	R	ARRAY	00631 L	10	PHICBY	R	ARRAY	0063B L	10
PHICBZ	R	ARRAY	00645 L	10	PHICPY	R	ARRAY	00659 L	10	PHICPZ	R	ARRAY	00663 L	10
PHICS1Y	R	ARRAY	00655 L	10	PHICS1Z	R	ARRAY	0069F L	10	PHICS2Y	R	ARRAY	006A9 L	10
PHICS2Z	R	ARRAY	006B3 L	10	PHICS3Y	R	ARRAY	00680 L	10	PHICS3Z	R	ARRAY	006C7 L	10
PHICTY	R	ARRAY	0066D L	10	PHICTZ	R	ARRAY	00677 L	10	PHIDY	R	SCALR	0002D L	1
PHIDZ	R	SCALR	0002C L	1	PHIR	R	ARRAY	00000 L	60	PHIRA	R	SCALR	006D3 L	1
PHIRB	R	SCALR	006D4 L	1	PHIRP	R	SCALR	006D1 L	1	PHIRS1	R	SCALR	006D5 L	1
PHIRS2	R	SCALR	006D6 L	1	PHIRS3	R	SCALR	006D7 L	1	PHIRT	R	SCALR	006D2 L	1
PHIY	R	SCALR	0002B L	1	PHIZ	R	SCALR	0002A L	1	PSICAX	R	ARRAY	0064F L	10
PSICBX	R	ARRAY	00348 L	10	R	R	ARRAY	00759 L	20	SQRT	R	SPROG	INTRIN	
UF	R	SCALR	00049 L	1	UPP	R	SCALR	0004C L	1	UPT	R	SCALR	00059 L	1
UT	R	SCALR	00056 L	1	VWP	R	SCALR	00046 L	1	VWT	R	SCALR	00053 L	1

```
X          R SCA R   CCC1E L       1        XD        R SCALR   00021 L       1       XIDY      R SCALR   00030 L      1
XIDZ       R SCA R   CCC31 L       1        XIY       R SCALR   0002E L       1       XIZ       R SCALR   0002F L      1
Y          R SCA R   CCC1F L       1        YD        R SCALR   00022 L       1       Z         R SCALR   00020 L      1
ZD         R SCA R   CCC23 L       1

        HEX               HEX              HEX              HEX              HEX              HEX
LABEL   LOC      LABEL    LOC     LABEL    LOC     LABEL    LOC     LABEL    LOC     LABEL    LOC
-----   -----    -----    -----   -----    -----   -----    -----   -----    -----   -----    -----
  5CC   CC573       5C1   008CC

LOCAL VARIABLE  (1 WORD))

   CCCCC DELTA

BLANK COMMON (   WORDS)

LABELED COMMON BLOCK /DELTIN/ (96 WORDS))

   CCCCC DELPY        C0001 DELPZ        00002 DELTP        00003 DELTZ        00004 DELAY        00005 DELAZ
   CCCC6 DELBX        C0007 DELS1Y       00008 DELS3Y       00009 DELS3Y       0000A DELS1Z       0000B DELS2Z
   CCCCC DELS3        0000D DELP         0000E DELT         0000F DELA         00010 DMIN         00011 DELDPY
   CCC12 DELCP        CC013 DELDTY       00014 DELDAZ       00015 DELDBX       00016 DELDAY       00017 DELDAZ
   CCC18 DELDS Y      00019 DELDS2Y      0001A DELDS3Y      0001B DELDS1Z      0001C DELDS2Z      0001D DELDS3Z
   CCC1E X            CC01F Y            00020 Z            00021 XD           00022 YD           00023 ZD
   CCC24 LP           C0025 LT           00026 LA           00027 LS1          00028 LS2          00029 LS3
   CCC2A PHIZ         CC02B PHIY         0002C PHIDV        0002D PHIDY        0002E XIY          0002F XIZ
   CCC3C XIDY         00031 XIDZ         00032 ETA          0003C ETAD         00046 VNP          00047 GPP
   CCC48 GP           C0049 UP           0004A DELPGY       0004B DELPPZ       0004C UPP          0004D DPPPY
   CCC4E DEPPZ        C004F DELDPPY      00050 DELDPPZ      00051 DDPPPY       00052 DDPPPZ       00053 VNT
   CCC54 GPT          0C055 GT           00056 UT           00057 DELPTY       00058 DELPTZ       00059 UPT
   CCC5A DPPTY        COC5B DPPTZ        0005C DELDPTY      0005D DELDPTZ      0005E DDPPTY       0005F DDPPTZ

LABELED COMMON BLOCK /BENDIN/ (1963 WORDS))

   CCCCC PHIR         0C03C FEER         00078 PHIC         00348 PSICBX       00352 FEEC         00622 MODC
   CC623 IRF          CC624 IRT          00625 IRA          00626 IRB          00627 IRS1         00628 IRS2
   CC629 IRS3         0C62A ICB          0062B ICA          0062C ICP          0062D ICT          0062E ICS1
   CC62F ICS2         CC630 ICS3         00631 PHICKX       0063B PHICBY       00645 PHICBZ       0064F PSICAX
   CC659 PHICP        C0663 PHICPZ       0066D PHICAY       00677 PHICTZ       00681 PHICAY       0068B PHICAZ
   CC695 PHICS Y      C069E PHICS1Z      006A9 PHICS2Y      006B3 PHICS2Z      006BD PHICS3Y      006C7 PHICS3Z
   CC6D1 PHIRP        0C6D2 PHIRT        006D3 PHIRI        006D4 PHIRB        006D5 PHIRS1       006D6 PHIRS2
   CC6D7 PHIRS        CC6D8 AC1          006E2 AC2          006EC AC3          006F6 AC4          00700 AC5
   CC70A AC6          C0714 AC7          0071E CAC1         00721 CAC2         00724 CAC3         00727 CAC4
   CC72A CAC5         C072D CAC6         00730 CAC7         00733 DAC1         00736 DAC2         00739 DAC3
   CC73C DAC4         CC73F DAC5         CC742 DAC6         00745 DAC7         00748 JAC1         00749 JAC2
   CC74A JAC3         C074B JAC4         0074C JAC5         0074D JAC6         0074E JAC7         0074F OHMC
   CC75S R            0C76D APR          0077C AIR1         0078B AIR2         0079A AIR3         007A9 OHMR
   CC7AA OHMRS
```

A34

ORIGINAL PAGE IS
OF POOR QUALITY

```
ENTRY POINTS:

   00000 DELTA

INTRINSIC SUBPROGRAMS USED:

   SQRT

EXTERNAL SUBPROGRAMS REQUIRED:

   SSETLPC     SQRT

HIGHEST ERROR SEVERITY: 0 (NO ERRORS)

                    DEC       HEX
                   WORDS     WORDS
                   -----     -----
  GENERATED CODE :  1485     005CD
        CONSTANT :     0     00000
  LOCAL VARIABLE :     1     00001
            TEMP :    12     0000C
                   -----     -----
   TOTAL PROGRAM :  1498     005DA    (PLUS LABELED COMMON)
```

A35

ORIGINAL PAGE IS
OF POOR QUALITY

```
      SUBROUTINE BENDING
C     THIS SUBROUTINE READS THE DISK FILE CONTAINING ALL BENDING MODES
C     AND SETS PROGRAM PARAMETERS BASED ON INPUT DATA PARAMETERS...
C
      COMMON /BENDIN/ PHIR(3,20,1),FTER(3,20,1),PHIC(3,24,10),PSICBX(10)
     *,FEEC(3,24,10),MOCC,IRP,IRT,IRI,IRB,IRS1,IRS2,IRS3,ICB,ICA,ICP,ICT
     *,ICS1,ICS2,ICS3,PHICBX(10),PHIMBY(10),PHICBZ(10),PSICAX(10)
     *,PHICPY(10),PHICPZ(10),PHICTY(20),PHICTZ(10),PHICAY(10),PHICAZ(10)
     *,PHICS1Y(10),PHICS1Z(10),PHICS3Y(10),PHICS2Z(10),PHICS3Y(10)
     *,PHICS3Z(10),PHIRF,PHIRT,PHIRA,PHIRB,PHIRS1,PHIRS2,PHIRS3
     *,AC1(10),AC2(10),AC3(10),AC4(11),AC5(10),AC6(10),AC7(10)
     *,CAC1(3),CAC2(3),CAC3(3),CAC4(4),CAC5(3),CAC6(3),CAC7(3)
     *,DAC1(3),DAC2(3),DAC3(3),DAC4(4),DAC5(3),DAC6(3),DAC7(3)
     *,JAC1,JAC2,JAC3,JAC4,JAC5,JAC6,JAC7
     *,OMMC(10),R(20),AMR(15),AIR1(10),AIR2(10),AIR3(15),OMMR,OMMRS8
C                                                                    127
C    NPUT BENDING DATA                                               128
C                                                                    129
      NAME LIST
      INPUT(200)                                                     130
      REWIND 200
C
C     FEEC(I,J,K) (PHIC(I,J,K)) IS THE DISPLACEMENT (ROTATION) PORTION
C     IN THE ITH AXIS (1=X,2=Y,3=Z)
C     OF THE JTH JOINT
C     OF THE KTH MODE...
C
      DO 1003 K=1,MODC,1                                             131
      PHICBX(K)= FEEC(1,ICB,K)                                       132
      PHICBY(K)= FEEC(2,ICB,K)                                       133
      PHICBZ(K)= FEEC(3,ICB,K)                                       134
      PSICAX(K)= PHIC(1,ICA,K)                                       135
      PHICPY(K)= FEEC(2,ICP,K)                                       136
      PHICPZ(K)= FEEC(3,ICP,K)                                       137
      PHICTY(K)= FEEC(2,ICT,K)                                       138
      PHICTZ(K)= FEEC(3,ICT,K)                                       139
      PHICAY(K)= FEEC(2,ICA,K)                                       140
      PHICAZ(K)= FEEC(3,ICA,K)                                       141
      PHICS1Y(K)= FEEC(2,ICS1,K)                                     142
      PHICS1Z(K)= FEEC(3,ICS1,K)                                     143
      PHICS2Y(K)= FEEC(2,ICS2,K)                                     144
      PHICS2Z(K)= FEEC(3,ICS2,K)                                     145
C
C     THIS SEAL IS NOT IN FUEL PUMP, HENCE...
C     IF (ICS3.GT.0) PHICS3Y(K)=FEEC(2,ICS3,K);PHICS3Z(K)=FEEC(3,ICS3,K)
C
 1003 CONTINUE                                                       155
C
C                   ACCELOROMETER CALCULATION
C
C    MOCC IS THE NUMBER OF MODES FOR EACH ACCEL.  (MAX = 10)
C    JAC1 IS THE JOINT NUMBER CORRESPONDING TO ACCELOROMETER NUMBER 1
C
```

```
      DO 3000  K=1,MOCC
      AC1(K)=0.
      AC2(K)=0.
      AC3(K)=0.
      AC4(K)=0.
      AC5(K)=0.
      AC6(K)=0.
      AC7(K)=0.
      DO 3000  I=1,3
C     I = 1,2,3  IMPLIES X,Y,Z AXES, RESPECTIVELY
      AC1(K)=(CAC1(I)*FEEC(I,JAC1,K)/DAC1(I)*PHIC(I,JAC1,K))/386.*
     *+AC1(K)
      AC2(K)=(CAC2(I)*FEEC(I,JAC2,K)/DAC2(I)*PHIC(I,JAC2,K))/386.*
     *+AC2(K)
      AC3(K)=(CAC3(I)*FEEC(I,JAC3,K)/DAC3(I)*PHIC(I,JAC3,K))/386.*
     *+AC3(K)
      AC4(K)=(CAC4(I)*FEEC(I,JAC4,K)/DAC4(I)*PHIC(I,JAC4,K))/386.*
     *+AC4(K)
      AC5(K)=(CAC5(I)*FEEC(I,JAC5,K)/DAC5(I)*PHIC(I,JAC5,K))/386.*
     *+AC5(K)
      AC6(K)=(CAC6(I)*FEEC(I,JAC6,K)/DAC6(I)*PHIC(I,JAC6,K))/386.*
     *+AC6(K)
      AC7(K)=(CAC7(I)*FEEC(I,JAC7,K)/DAC7(I)*PHIC(I,JAC7,K))/386.*
     *+AC7(K)
 3000 CONTINUE
C
      PHIRP= FEER(2,IRP,1)                                              155
      PHIRT= FEER(2,IRT,1)                                              157
      PHIRA= FEER(2,IRA,1)                                              158
      PHIRB= FEER(2,IRB,1)                                              159
      PHIRS1= FEER(2,IRS1,1)                                            160
      PHIRS2= FEER(2,IRS2,1)                                            161
C
C     THIS SEAL IS NOT IN FUEL PUMP, HENCE...
      IF (IRS3.GT.0) PHIRS3=FEER(2,IDS3,1)
      RETURN
      END
```

NAME	TYPE	CLASS	HEX LOC	DEC WORDS	NAME	TYPE	CLASS	HEX LOC	DEC WORDS	NAME	TYPE	CLASS	HEX LOC	DEC WORDS
AC1	R	ARRAY	006D8 L	10	AC2	R	ARRAY	006E2 L	10	AC3	R	ARRAY	006EC L	10
AC4	R	ARRAY	006F6 L	10	AC5	R	ARRAY	00700 L	10	AC6	R	ARRAY	0070A L	10
AC7	R	ARRAY	00714 L	10	AIR1	R	ARRAY	0077C L	15	AIR2	R	ARRAY	0078B L	15
AIR3	R	ARRAY	0079A L	15	AIR	R	ARRAY	0076D L	15	BENDING	R	SCALR	00000 V	1
BENDING		SFR G	00000 P		CAC1	R	ARRAY	0071E L	3	CAC2	R	ARRAY	00721 L	3
CAC3	R	ARRAY	00724 L	3	CAC4	R	ARRAY	00727 L	3	CAC5	R	ARRAY	0072A L	3
CAC6	R	ARRAY	0072D L	3	CAC7	R	ARRAY	00730 L	3	DAC1	R	ARRAY	00733 L	3
DAC2	R	ARRAY	00736 L	3	DAC3	R	ARRAY	00739 L	3	DAC4	R	ARRAY	0073C L	3
DAC5	R	ARRAY	0073F L	3	DAC6	R	ARRAY	00742 L	3	DAC7	R	ARRAY	00745 L	3
FEEC	R	ARRAY	00352 L	720	FEER	R	ARRAY	0003C L	60	I	I	SCALR	00002 V	1
ICA	I	SCALR	0062B L	1	ICB	I	SCALR	0062A L	1	ICP	I	SCALR	0062C L	1
ICS1	I	SCALR	0062E L	1	ICS2	I	SCALR	0062F L	1	ICS3	I	SCALR	00630 L	1
ICT	I	SCALR	0062D L	1	IRA	I	SCALR	00625 L	1	IRB	I	SCALR	00626 L	1
IRE	I	SCALR	00623 L	1	IRS1	I	SCALR	00627 L	1	IRS2	I	SCALR	00628 L	1
IRS3	I	SCALR	00629 L	1	IRT	I	SCALR	00624 L	1	JAC1	I	SCALR	00748 L	1
JAC2	I	SCALR	00749 L	1	JAC3	I	SCALR	0074A L	1	JAC4	I	SCALR	0074B L	1
JAC5	I	SCALR	0074C L	1	JAC6	I	SCALR	0074D L	1	JAC7	I	SCALR	0074E L	1
K	I	SCALR	00001 V	1	MODC	I	SCALR	00622 L	1	OHMC	R	ARRAY	0074F L	10
OHMR	R	SCALR	007A9 L	1	OHMRSQ	R	SCALR	007AA L	1	PHIC	R	ARRAY	00078 L	720
PHICAY	R	ARRAY	00681 L	10	PHICAZ	R	ARRAY	0068B L	10	PHICBX	R	ARRAY	00631 L	10
PHICBY	R	ARRAY	0063B L	10	PHICBZ	R	ARRAY	00645 L	10	PHICPY	R	ARRAY	00659 L	10
PHICPZ	R	ARRAY	00663 L	10	PHICS1Y	R	ARRAY	00695 L	10	PHICS1Z	R	ARRAY	0069F L	10
PHICS2Y	R	ARRAY	006A9 L	10	PHICS2Z	R	ARRAY	006B3 L	10	PHICS3Y	R	ARRAY	006BD L	10
PHICS3Z	R	ARRAY	006C7 L	10	PHICTY	R	ARRAY	0066D L	10	PHICTZ	R	ARRAY	00677 L	10
PHIR	R	ARRAY	00000 L	60	PHIRA	R	SCALR	006D3 L	1	PHIRB	R	SCALR	006D4 L	1
PHIRE	R	SCALR	006D1 L	1	PHIRS1	R	SCALR	006D5 L	1	PHIRS2	R	SCALR	006D6 L	1
PHIRS3	R	SCALR	006D7 L	1	PHIRT	R	SCALR	006D2 L	1	PSICAX	R	ARRAY	0064F L	10
PSICBX	R	ARRAY	00348 L	10	R	R	ARRAY	00759 L	20					

LABEL	HEX LOC	LABEL	HEX LOC	LABEL	HEX LOC	LABEL	HEX LOC	LABEL	HEX LOC	LABEL	HEX LOC
1003	0006B	3000	000E5								

LOCAL VARIABLE (3 WORDS)!

00000 BENDING   00001 K   00002 I

BLANK COMMON (WORDS)

LABELED COMMON BLOCK /BENDIN/ (1963 WORDS)!

00000 PHIR	0003C FEER	00078 PHIC	00348 PSICBX	00352 FEEC	00622 MODC
00623 IRE	00624 IRT	00625 IRA	00626 IRB	00627 IRS1	00628 IRS2
00629 IRS3	0062A ICB	0062B ICA	0062C ICP	0062D ICT	0062E ICS1
0062F ICS2	00630 ICS3	00631 PHICBX	0063B PHICBY	00645 PHICBZ	0064F PSICAX
00659 PHICP	00663 PHICPZ	0066D PHICTY	00677 PHICTZ	00681 PHICAY	0068B PHICAZ

```
CC695 PHICS Y    0C69F PHICS1Z   006A9 PHIC02Y   006B3 PHICS2Z   006BD PHIC03Y   006C7 PHICS3Z
CC6C1 PHIRP      CC6D2 PHIRT     0C6D3 PHIRI     006D4 PHIRB     006D5 PHIRS1    006D6 PHIRS2
CC6C7 PHIRS      CC6D8 AC1       006E2 AC2       006EC AC3       006F6 AC4       00700 AC5
CC70A AC6        CC714 AC7       0071E CAC1      00721 CAC2      00724 CAC3      00727 CAC4
CC72A CAC5       CC72D CAC6      00730 CAC7      00733 DAC1      00736 DAC2      00739 DAC3
CC73C DAC4       CC73F DAC5      00742 DAC6      00745 DAC7      00748 JAC1      00749 JAC2
CC74A JAC3       CC74B JAC4      0074C JAC5      0074D JAC6      0074E JAC7      0074F OHMC
CC765 R          CC76D AMR       0C77C AIR1      0078B AIR2      0079A AIR3      007A9 OHMR
CC7AA OHMRS

ENTRY POINTS:

   CCC2C BENDI G

EXTERNAL SUBPR GRAMS REQUIRED:

   SINGLT        REWIND     99ETUPO

HIGHEST ERROR  EVERITY: 0 (NO ERRORS)

                     DEC        HEX
                    WORDS      WORDS
                    .....      .....
GENERATED COD  :      761      002F9
      CONSTANT :        1      00001
LOCAL VARIABLE :        3      0000C3
          TEMP :        2      00002
                    .....      .....
 TOTAL PROGRA  :      767      002FF    (PLUS LABELED COMMON)
```

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ORIGINAL PAGE IS
OF POOR QUALITY

```
      SUBROUTINE JOUR1(XD,YD,X,Y,OMB,E,FX,FY)                       885
      COMMON/DATAJB/CL,C1,D2,D3,ELOD3,PI2,EMAX
C                                                                   887
C     ******************************************                    888
C        THIS IS THE MOES IMPEDANCE FNR THE       *                 889
C     CAVITATING PLAIN FULL JOURNAL BEARING       *                 890
C     ******************************************                    891
C                                                                   892
      DATA PI/3.14159265/                                           893
      CALL SQUACT(X,Y,XD,YD,OMB,E,VS,CAL,SAL,AL,COA,SOA)
      IF(E.GT.EMAX) E=EMAX
C                                                                   896
      PE=E*CAL                                                      897
      PN=E*SAL                                                      898
      C1=(1.-E*E)/ELOD2
      C2=SQRT(1.-PN**2)                                             901
      A1=4.*(1.+2.12*C1)*C2/(3.*(1.+4.60*C1))                       902
      ASPN=ARSIN(PN)                                                903
      A1=ATAN2(A1,PN)-.5*PI+ASPN                                    904
      GAM=(1.-PE/C2)*A1+AL-ASPN                                     905
      PSI=AL-GAM                                                    906
C                                                                   907
      PE=E*COS(GAM)                                                 908
      PN=E*SIN(GAM)                                                 909
      CC=1.-PE                                                      910
      C1=CC/ELOD2
      C2=.150*CC*SQRT(CC)                                           912
      A=1.+2.12*C1                                                  913
      B=.75*PN*(1.+3.6*C1)/CC                                       914
C                                                                   915
      W=1./C2/SQRT(A*A+B*B)                                         916
      WX=W*COS(PSI)                                                 917
      WY=W*SIN(PSI)                                                 918
C                                                                   919
      FX=-VS*(WX*COA-WY*SOA)*D1                                     920
      FY=-VS*(WX*SOA+WY*COA)*D1                                     921
C                                                                   922
      RETURN                                                        923
C                                                                   924
      END                                                           929
```

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ORIGINAL PAGE IS OF POOR QUALITY

NAME	TYPE	CLASS	HEX LOC	DEC WORDS	NAME	TYPE	CLASS	HEX LOC	DEC WORDS	NAME	TYPE	CLASS	HEX LOC	DEC WORDS
A	R	SCA R	00012 V	1	AL	R	SCALR	00006 V	1	ARSIN	R	SPROG	INTRIN	
ASPN	R	SCA R	0000E V	1	ATAN2	R	SPROG	INTRIN		A1	R	SCALR	0000D V	1
B	R	SCA R	00013 V	1	CAL	R	SCALR	00004 V	1	COA	R	SCALR	00007 V	1
CL	R	SCA R	00000 L	1	COS	R	SPROG	INTRIN		CO	R	SCALR	00011 V	1
C1	R	SCA R	0000B V	1	C2	R	SCALR	0000C V	1	D1	R	SCALR	00001 L	1
D2	R	SCA R	00002 L	1	D3	R	SCALR	00003 L	1	E	R	SCALR	00002 V	1
ELOD2	R	SCA R	00004 L	1	EMAX	R	SCALR	00006 L	1	FX	R	SCALR	*0001C V	DUMMY
FY	R	SCA R	*0001D V	DUMMY	GAM	R	SCALR	0000F V	1	JOUR1	I	SCALR	00000 V	1
OBLR1		SPR G	00000 P		OMB	R	SCALR	*0001B V	DUMMY	PE	R	SCALR	00009 V	1
PI	R	SCA R	00001 V	1	PI2	R	SCALR	00005 L	1	PN	R	SCALR	0000A V	1
PSI	R	SCA R	00010 V	1	SAL	R	SCALR	00005 V	1	SOA	R	SCALR	00008 V	1
SIN	R	SPR G	INTRIN		SQRT	R	SPROG	INTRIN		SQUACT		SPROG	EXTERN	
VS	R	SCA R	00003 V	1	W	R	SCALR	00014 V	1	WX	R	SCALR	00015 V	1
WY	R	SCA R	00016 V	1	X	R	SCALR	*00019 V	DUMMY	XD	R	SCALR	*00017 V	DUMMY
Y	R	SCA R	*0001A V	DUMMY	YD	R	SCALR	*00018 V	DUMMY					

LOCAL VARIABLE (23 WORDS):

```
00000 JOUR     00001 PI     00002 E      00003 VS     00004 CAL    00005 SAL
00006 AL       00007 COA    00008 SOA    00009 PE     0000A PN     0000B C1
0000C C2       0000D A1     0000E ASPN   0000F GAM    00010 PSI    00011 CO
00012 A        00013 B      00014 W      00015 WX     00016 WY
```

BLANK COMMON (WORDS)

LABELED COMMON BLOCK /DATAJB/ (7 WORDS):

```
00000 CL       00001 D1     00002 D2     00003 D3     00004 ELOD2  00005 PI2
00006 EMAX
```

ENTRY POINTS:

```
00000 OBLR1
```

INTRINSIC SUBPROGRAMS USED:

```
ARSIN     ATAN2     COS     SIN     SQRT
```

EXTERNAL SUBPROGRAMS REQUIRED:

```
SQUACT    ASIN    9ATAN2    9COS    *SETUPN    9SIN    9SQRT
```

HIGHEST ERROR SEVERITY: 0 (NO ERRORS)

```
                    DEC      HEX
                   WORDS    WORDS
                   -----    -----
GENERATED COD  !    153     00099
     CONSTANT  !      8     00008
LOCAL VARIABLE !     23     00017
         TEMP  !     10     0000A
                   -----    -----
TOTAL PROGRA   !    194     000C2   (PLUS LABELED COMMON)
```

```
      SUBROUTINE JOUR2(XD,YD,X,Y,OMBEFX,FY)                                930
      COMMON/DATAJB/CL,D1,D2,D3,ELOD3,PI2,EMAX
C** *********                                                             932
C      THIS IS THE MOBS IMPEDANCE FOR THE NON-                            933
C      CAVITATING 2 PI PLAIN FULL JOURNAL BEARING                         934
C** ********                                                              935
C                                                                         936
      DATA PI/3.14159265/                                                 937
      CALL SQUACT(X,Y,XD,YD,OMB,E,VSECAL,SAL,AL,COA,SOA)
      IF(E.GT.EMAX) E=EMAX
C                                                                         940
       E2=E*E                                                             941
       EC=1.-E2                                                           942
      EB=E2+E2+1.
      WE =PI*EB*D2*CAL/EL/EL/SQRT(EC)
      WB=-PI*D2*SAL/EL/SQRT(EC)
C                                                                         947
       WX=WE*CAL-WB*SAL                                                   948
       WY=WE*SAL+WB*CAL                                                   949
C                                                                         950
       FX=-VS*(WX*COA-WY*SOA)*D1                                          951
       FY=-VS*(WX*SOA+WY*COA)*D1                                          952
       RETURN                                                             953
       END                                                                958
```

```
NAME    TYPE CLASS    HEX    DEC     NAME    TYPE CLASS    HEX    DEC     NAME    TYPE CLASS    HEX    DEC
                      LOC    WORDS                         LOC    WORDS                         LOC    WORDS
----    ---- -----  -------  -----   ----    ---- -----  -------  -----   ----    ---- -----  -------  -----
AL         R SCALR   00006 V     1   CAL        R $CALR   00004 V     1   COA        R SCALR   00007 V     1
CL         R SCALR   00000 L     1   D1         R $CALR   00001 L     1   D2         R SCALR   00002 L     1
D3         R SCALR   00003 L     1   E          R $CALR   00002 V     1   EB         R SCALR   0000B V     1
EC         R SCALR   0000A V     1   EL         R $CALR   0000D V     1   ELOD2      R SCALR   00004 L     1
EMAX       R SCALR   00006 L     1   E2         R $CALR   00009 V     1   FX         R SCALR  *00016 V DUMMY
FY         R SCALR  *00017 V DUMMY   JOUR2        $PROG   00000 P         JOUR2      I SCALR   00000 V     1
GME        R SCALR  *00015 V DUMMY   PI         R $CALR   00001 V     1   PI2        R SCALR   00005 L     1
SAL        R SCALR   00005 V     1   SOA        R $CALR   00008 V     1   SQRT       R SPROG   INTRIN
SGLACT       SPROG   EXTERN          VS         R $CALR   00003 V     1   WB         R SCALR   0000E V     1
WE         R SCALR   0000C V     1   WX         R $CALR   0000F V     1   WY         R SCALR   00010 V     1
X          R SCALR  *00013 V DUMMY   XD         R $CALR  *00011 V DUMMY   Y          R SCALR  *00014 V DUMMY
YC         R SCALR  *00012 V DUMMY

LOCAL VARIABLE (17 WORDS):

    00000 JOUR2     00001 PI      00002 E       00003 VS      00004 CAL     00005 SAL
    00006 AL        00007 COA     00008 SOA     00009 E2      0000A EC      0000B EB
    0000C WE        0000D EL      0000E WB      0000F WX      00010 WY

BLANK COMMON (   WORDS)

LABELED COMMON BLOCK /DATAJB/ (7 WORDS):

    00000 CL        00001 D1      00002 D2      00003 D3      00004 ELOD2   00005 PI2
    00006 EMAX

ENTRY POINTS:

    00000 JOUR2

INTRINSIC SUBPROGRAMS USED:

    SQRT

EXTERNAL SUBPROGRAMS REQUIRED:

    SGLACT       SETLFN      $SQRT

HIGHEST ERROR SEVERITY: 0 (NO ERRORS)

                    DEC         HEX
                    WORDS       WORDS
                    -----       -----
  GENERATED CODE :    95        0005F
```

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```
        CONSTANT |      1     C0001
LOCAL VARIABLE  |     12     C0011
            TEMP |      9     C0009
                   -----     -----
   TOTAL PROGRA |    122     0007A    (PLUS LABELEL COMMON)
```

C-2

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```
      SUBROUTINE JOUR3(XD,YD,X,Y,PHSD,FX,FY)                    959
      COMMON/DATAJB/CL,C1,D2,D3,ELOD3,PI2,EMAX
C                                                               961
C     LINEARIZED CAVITATING DAMPER MODEL                        962
C                                                               963
     DATA PI/3.141592654/                                       966
      C1=2.12                                                   967
      C2=3.6                                                    968
     C1=1./ELOD2
      BC=(1.-E)*C                                               970
      A=1.+C1*BC                                                971
      B=1.+C2*BC                                                972
      GAMO=ATAN(4.*A*SQRT(1.-E*E)/(4.*B*E))                     973
      COAM=COS(GAMO)                                            974
      SOAM=SIN(GAMO)                                            975
      XC=E*COAM                                                 976
      YC=E*SOAM                                                 977
      D=(1.-XC)                                                 978
      G=D*C                                                     979
      EC=1.+C1*G                                                980
      GO=3.*YC*(1.+C2*G)/4./D                                   981
      H2=EC*EC+GO*GO                                            982
      H=SQRT(H2)                                                983
      HO=1./(.18*H*D**1.8)                                      984
      AK=HO*COAM*PHID*C1                                        985
      AC=HO*SOAM*D1                                             986
      FX=-(AK*X+AC*XD)                                          987
      FY=-(AK*Y+AC*YD)                                          988
      RETURN                                                    989
      END                                                       990
```

NAME	TYPE	CLASS	HEX LOC	DEC WORDS	NAME	TYPE	CLASS	HEX LOC	DEC WORDS	NAME	TYPE	CLASS	HEX LOC	DEC WORDS
A	R	SCA R	CCCC7 V	1	AC	R	SCALR	00016 V	1	AK	R	SCALR	00015 V	1
ATAN	R	SFR G	INTRIN		B	R	SCALR	00008 V	1	BO	R	SCALR	00004 V	1
C	R	SCA R	CCC06 V	1	COAM	R	SCALR	0000A V	1	CL	R	SCALR	00000 L	1
COS	R	SFR G	INTRIN		C1	R	SCALR	00002 V	1	C2	R	SCALR	00003 V	1
D	R	SCA R	CCCCE V	1	D1	R	SCALR	00001 L	1	D2	R	SCALR	00002 L	1
D3	R	SCA R	CCCC3 L	1	E	R	SCALR	00005 V	1	ELOD2	R	SCALR	00004 L	1
EMAX	R	SCA R	C0006 L	1	EO	R	SCALR	00010 V	1	EX	R	SCALR	*0001C V	DUMMY
FY	R	SCA R	*CCC1D V	DUMMY	GAMO	R	SCALR	00009 V	1	GO	R	SCALR	00011 V	1
H	R	SCA R	CCC13 V	1	H2	R	SCALR	00012 V	1	WOUR3		SPROG	0C000 P	
VOLF3	I	SCA R	CC000 V	1	PHID	R	SCALR	*0001B V	DUMMY	PI	R	SCALR	00001 V	1
PI2	R	SCA R	C0005 L	1	Q	R	SCALR	0000F V	1	SGAM	R	SCALR	0000B V	1
SIN	R	SFR G	INTRIN		SQRT	R	SPROG	INTRIN		WO	R	SCALR	00014 V	1
X	R	SCA R	*CCC19 V	DUMMY	XD	R	SCALR	*00017 V	DUMMY	XO	R	SCALR	0000C V	1
Y	R	SCA R	*CCC1A V	DUMMY	YD	R	SCALR	*00018 V	DUMMY	YO	R	SCALR	0000D V	1

LOCAL VARIABLE (23 WORDS):

CCCCC	VOLF3	0CC01	PI	00002	C1	00C03	C2	00004	BO
00005	E	CCCC6	C	0CC07	A	00008	B	00009	GAMO
0000A	COAM	0000B	SGAM	CCCCC	XC	C000D	YO	0000E	D
0000F	Q	00010	EO	00011	GO	CCC12	H2	0C013	H
00014	WO	00015	AK	00016	AC				

BLANK COMMON (WORDS)

LABELED COMMON BLOCK /DATAJB/ (7 WORDS):

CCCCC	CL	C0001	D1	00002	D2	00003	D3	00004	ELOD2
00005	PI2	CCCC6	EMAX						

ENTRY POINTS:

CCCCC VOLF3

INTRINSIC SUBPROGRAMS USED:

ATAN COS SIN SQRT

EXTERNAL SUBPROGRAMS REQUIRED:

SATAN1 COS 9FNRRR 9SETUPN *SIN 9SQRT

HIGHEST ERROR SEVERITY: C (NO ERRORS)

DEC HEX

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```
                     WORDS      WORDS
                     -----      -----
GENERATED CODE  I     118       C0076
      CONSTANT  I       7       C0007
LOCAL VARIABLE  I      23       C0017
          TEMP  I       9       C0009
                     -----      -----
 TOTAL PROGRAM  I     157       C009D    (PLUS LABELED COMMON)
```

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```
      SUBROUTINE SQUACT(X,Y,XD,YD,OMK,E,VS,CAL,SAL,AL,COA,SOA)
      COMMON/DATAJB/CL,C1,C2,C3,ELOD3,PI2,EMAX
C                                                             993
C     ****************************************                994
C     * THIS ROUTINE COMPUTES THE ECCENTRICITY *              995
C     * AND SQUEEZE VELOCITY VECTORS           *              996
C     ****************************************                997
C                                                             998
C                                                            1002
      XDS=XD+OMK*Y                                           1003
      YDS=YD-OMK*X                                           1004
      VS=SQRT(XDS*XDS+YDS*YDS)                               1005
      IF(VS.EQ.0.)COA=1. / SOA=0. / GO TO 1
C                                                            1007
      COA=XDS/VS                                             1008
      SOA=YDS/VS                                             1009
C                                                            1010
    1 AE=SQRT(X*X+Y*Y)
      E=AE/CL                                                1012
      IF(E.EQ.0.)CAL=1. / SAL=0. / GO TO 2
C                                                            1016
      SBET=Y/AE                                              1017
      CBET=X/AE                                              1018
      SAL=SBET*COA-CBET*SOA                                  1019
      CAL=CBET*COA+SBET*SOA                                  1020
    2 AL=ATAN2(SAL,CAL)
      RETURN                                                 1032
      END                                                    1037
```

```
NAME  TYPE CLASS  HEX      DEC       NAME    TYPE CLASS   HEX       DEC       NAME    TYPE CLASS   HEX       DEC
                  LOC      WORDS                          LOC       WORDS                          LOC       WORDS
----  ---- -----  -------  -----     ----    ---- -----   -------   -----     ----    ---- -----   -------   -----
AE       R SCA R   OCCO3 V     1     AL         R SCALR  *0000F V DUMMY      ATAN2      R SPROG   INTRIN
CAL      R SCA R  *CCCOD V DUMMY     CBET       R SCALR   00005 V     1      COA        R SCALR  *00010 V DUMMY
CL       R SCA R   CCCCO L     1     C1         R SCALR   00001 L     1      C2         R SCALR   00002 L     1
C3       R SCA R   CCCC3 L     1     E          R SCALR  *00008 V DUMMY      ELOD2      R SCALR   C0004 L     1
EMAX     R SCA R   C0006 L     1     OMB        R SCALR  *0000A V DUMMY      PI2        R SCALR   00005 L     1
SAL      R SCA R  *CCCCE V DUMMY     SBET       R SCALR   00004 V     1      SOA        R SCALR  *00011 V DUMMY
SQRT     R SPR G   INTRIN            SQUACT     R SCALR   00C00 V     1      SQUACT       SPROG   00000 P
XS       R SCA R  *COCCC V DUMMY     X          R SCALR  *00006 V DUMMY      XD         R SCALR  *00008 V DUMMY
XDS      R SCA R   CCC01 V     1     Y          R SCALR  *00007 V DUMMY      YD         R SCALR  *00009 V DUMMY
YDS      R SCA R   COCC2 V     1

LABEL  HEX     LABEL  HEX      LABEL  HEX      LABEL  HEX      LABEL  HEX      LABEL  HEX
       LOC            LOC             LOC             LOC             LOC             LOC
-----  -----   -----  -----    -----  -----    -----  -----    -----  -----    -----  -----
    1  CCC2C       2  C00B3.

LOCAL VARIABLE  (6 WORDS)!

   CCCCC SQUAC       00001 XDS         00002 YDS         00003 AE          00004 SBET        00005 CBET

BLANK COMMON (  WORDS)

LABELED COMMON BLOCK /DATAJB/ (7 WORDS)!

   CCCCC CL          CCC01 C1          00002 C2          00003 C3          00004 ELOD2       00005 PI2
   CCCC6 EMAX

ENTRY POINTS!

   CCCCC SQUAC

INTRINSIC SUBPROGRAMS USED!

   ATAN2     SQRT

EXTERNAL SUBPROGRAMS REQUIRED!

   SATAN2    SETLFN    9SQRT

HIGHEST ERROR SEVERITY! C (NO ERRORS)

              DEC        HEX
              WORDS      WORDS
```

```
                        -----    -----
GENERATED CODE |     88      00058
      CONSTANT |      1      00001
LOCAL VARIABLE |      6      00006
          TEMP |     14      0000E
                        -----    -----
 TOTAL PROGRA |    109      0006D   (PLUS LABELED COMMON)
```

```
ASSIGN (M:GO,D ,FOBJ)
!LOAD (GO),(FILE,FP,FLEX),(UDC,1,6),(CORE,3000),(TASKS,5),(TEMP,1000))
: (LIB,USER,SYSTEM),(MAP,ALL)
:ASSIGN (F:115, 2,DAT1)
:ASSIGN (F:116, 2,DAT2)
:ASSIGN (F:1C1, YAC1),VFC
:ASSIGN (F:1C2, YAC1),VFC
:ASSIGN (F:122, YAC1),VFC
:ASSIGN (F:5,ST 80)
:ASSIGN (F:2CC, 2,BEND)
:ASSIGN (F:121, FA02)
:ASSIGN (F:3C1, 2,MOD1)
:ASSIGN (F:3C2, 2,MOD2)
:ASSIGN (F:3C3, 2,MOD3)
:ASSIGN (F:3C4, 2,MOD4)
:ASSIGN (F:3C5, 2,MOD5)
:ASSIGN (F:3C6, 2,MOD6)
:ASSIGN (F:3C7, 2,MOD7)
```

```
PROGRAM MAP
FOREGROUND PROGRAM

FILE  FF/FLEX
NUMBER OF SEGMENTS:       1  ROOT
                          C  COMMON
                          0  OVERLAY
                          C  PUBLIC LIBRARY
LIMITS:  FWA: 2000  LWA: 7BD7
BELAD      2
BLANK COMMON  BASE   7686  SIZE      0
PUBLIC LIBRARIES     NONE
TOTAL MEMORY SIZE:   5BD8/ 23512  WORDS
TOTAL FILE SIZE:     FA/  2BC  GRANULES
LIBRARY SIZE   134C/  4928  WORDS
PROGRAM ERROR SEVERITY  0

OVLOAD  FCB    ENTRY  UTSFWA  SIZE  RTSFWA  SIZE  DCBTAB
 7686   2CCC   2CCE    775A    3E8   7B42     96   771A

ROOT PART ONE

INPUT  LIBRARY  REF WL  LP BL  FWA   LWA   ENTRY  ROMERR  LDERR  GRAN
 4258   134C    8808   1ED68  2000  7BD7   21CE     0       0      1

CENTRAL SECTIONS

   ROM      1     200E    8232
   ROM      1     4C38    4048

   ROM      2     5820    1486
   ROM      2     5CEE      14

   ROM      3     5CFC     762
   ROM      3     6CF6       6

   ROM      4     6CFC     162
   ROM      4     619E      34

   ROM      5     61C0      96
   ROM      5     6220      26

   ROM      6     623A     126
   ROM      6     62B8      38

   ROM      7     62D8      9C
   ROM      7     6332      2C
```

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LLIE	281	63A6	28
LLIE	289	6364	2C
LLIE	297	63B4	69
LLIE	309	63EA	76
LLIE	314	6446	58
LLIE	319	647E	84
LLIE	324	64D2	35
LLIE	327	64F8	122
LLIE	412	6572	58
LLIE	452	65AC	30
LLIE	462	65CA	3C
LLIE	536	65E8	43C
LLIE	586	6796	9
LLIE	587	67A0	15
LLIE	589	67B0	2
LLIE	591	67B8	2
LLIE	595	67BA	14
LLIE	597	67C8	121
LLIE	658	6842	98
LLIE	666	68A4	127
LLIE	654	6924	36
LLIE	711	6948	147A
LLIE	758	6FCE	144
LLIE	812	6F9E	21
LLIE	815	6FB4	95
LLIE	823	7012	13

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LLIB	824	7C20	62
LLIB	828	7C5E	134
LLIB	838	7CE4	2C
LLIB	840	7CF8	B8
LLIB	846	7132	14
LLIB	847	7140	186
LLIB	864	71FA	31
LLIB	870	721A	64
LLIB	873	725A	226
LLIB	883	733C	23
LLIB	924	7384	41
LLIB	927	737E	E2
LLIB	931	73B8	74
LLIB	959	7402	119
LLIB	972	747A	272
LLIB	1C20	758A	13B
LLIB	1C68	7612	44
LLIB	1C85	763E	72

SDCA	F11C8	7687
SDCA	F1D0	768E
SDCA	F18C	769B
SDCA	F11C6	769C
SDCA	F11C5	76A3
SDCA	F1115	76AA
SDCA	F1116	76B1
SDCA	F11C1	76B8
SDCA	F11C2	76BF
SDCA	F1122	76C6
SDCA	F15	76CC
SDCA	F12CC	76D4
SDCA	F1121	76DB
SDCA	F13C1	76E2
SDCA	F13C2	76E9
SDCA	F13C3	76EC
SDCA	F13C4	76F7

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ORIGINAL PAGE IS OF POOR QUALITY

```
SDCR     F13C5          76FE
SDCR     F13C6          770E
SDCR     F13C7          770C
SDCR     UNNAMED        77?3

CSCT IM  686 C       6 F4ICOM
 CEF IM  BC8 C         FIEND
 CEF IM  C0C C         UIPCB
CSCT IM  C06 C       7 DATAJB
CSCT IM  CCE C       5 T
CSCT IM  C14 0    1963 BENDIN
CSCT IM  7CC C      96 DELTIN
 CEF LL  4C6 C         NDAC
 CEF IM  DEC C         BENDING
 CEF LL  37E C         RSL
 CEF LL  796 C         EXIT
 CEF LL  3B8 C         NCL
 CEF IM  82C C         DELTAS
 CEF IM  CFC C         JOUR1
 CEF IM  1CC C         JOUR2
 CEF LL  572 C         BUFFOUT
 CEF LL  354 C         NCW
 CEF LL  7C8 C         9INITIAL
 CEF LL  EE8 C         9INPUT
 CEF LL  846 C         9BCDRDEE
 CEF LL  F3E C         9IODATA
 CEF LL  8A4 C         9PRINT
 CEF LL  F6D C         9ENDIOL
 CEF LL  8A5 C         9BCDWRIT
 CEF LL  843 C         9BCDREAD
 CEF LL  5AC C         9REWIND
 CEF LL  924 C         9IOLUSA
 CEF LL  7A4 C         9ITOR
 CEF LL  7BC C         9RTOI
 CEF LL  4BF C         9SIN
 CEF LL  49A C         9COS
 CEF LL  4D7 C         9SQRT
 CEF LL  5CA C         9ENDFILE
 CEF LL  C2C C         9STOP
 CEF IM  CCE 0         4MAIN
 CEF IM  C36 C         V#4MAIN
 CEF LL  788 C         9SETUPC
 CEF IM  CEE C         V#DELTAS
 CEF IM  CF6 C         V#BENDING
 CEF IM  208 C         9GUACT
 CEF LL  78A C         9SETUPN
 CEF LL  34A C         9ASIN
 CEF LL  376 C         9ATAN2
 CEF IM  19E C         V#JOUR1
 CEF IM  22C C         V#JOUR2
 CEF IM  23A C         JOUR3
 CEF LL  375 C         9ATAN1
 CEF LL  3B8 C         9PWRRF
```

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ORIGINAL PAGE IS OF POOR QUALITY

```
CEF IM     288 C     V*JOUR3
CEF IM     332 C     V*SGUACT
CEF LL     349 C     5ACOS
CEF LL     4F8 C     9ERROR
CEF LL     36A C     7ATAN1
CEF LL     364 C     7ATAN2
CEF LL     365 C     7ATAN3
CEF UL     4CC O     7ALOG2
CEF LL     468 C     7EXP2
CEF LL     46B C     7EXP1
CEF LL     4CE C     9ALOG
CEF LL     419 C     7ALOG
CEF LL     41D C     7ALOG1
CEF LL     3FA C     7ALOG3
CEF LL     45B C     5EXP
CEF LL     448 C     7EXP3
CEF LL     45A C     7EXP4
CEF LL     44A C     7EXP5
CEF LL     44C C     7EXP6
CEF LL     456 C     7EXP7
CEF LL     140 C     7ERRHEAD
CEF LL     186 C     7ERRTEXT
CEF LL     1C2 C     7PAC
CEF LL     1BC C     7PRC
CEF LL     1CC C     7PRO
CEF LL     228 C     8TALPHA
CEF LL     2CE C     8TR4TMP
CEF LL     C77 C     5RSAVE
CEF LL     22D C     8ALPHAT
CEF UL     22E C     8MSGBUF
CEF LL     572 C     8UFFOU
CEF LL     FF7 C     7BCDMODE
CEF LL     FF2 C     7BINMODE
CEF LL     FB4 O     7UNITADR
CEF LL     3CE C     8DCBADR
CEF LL     22B C     8IODLINK
CEF LL     251 C     8BUFFIOT
CEF LL     24B C     8TBUFFIO
CEF LL     318 C     8UNITT
CEF UL     213 C     8FPTADD
CEF LL     CF8 C     7GETNBUF
CEF LL     316 C     6ENDEG
CFF UL     317 C     6ERREG
CEF LL     19E C     7ERRMARK
CEF LL     C12 C     7GETMODE
CEF LL     1CB O     7PRL
CEF LL     869 C     7READ
CEF LL     2AD C     8BCDBUF
CEF LL     2F7 C     8BUFORG
CEF LL     33C C     8TINPUT
CEF LL     948 C     9IEDIT
CEF LL     CE4 C     7GETBUF
CEF LL     3C2 C     8EDITT
```

A57

ORIGINAL PAGE IS
OF POOR QUALITY

CEF	LL	352	O	8INPUTT
CEF	LL	24A	C	8MSGERRT
CEF	LL	218	C	8LODCBAC
CEF	LL	C2C	C	7STOP
CEF	LL	7A2	C	9ITOD
CEF	LL	7B1	C	9DTOI
CEF	LL	7BA	C	9SETUPM
CEF	LL	7BB	C	7SET
CEF	LL	7CC	C	EOO
CEF	LL	2C8	C	8FPTACR
CEF	LL	2C9	C	8RTBSFTR
CEF	LL	2CA	C	8TO
CEF	LL	C92	C	9REXIT
CEF	LL	1CA	C	7PHC
CEF	LL	1DF	C	7ERRINIT
CEF	LL	314	C	6DCBNAME
CEF	LL	2C6	C	8ABORTEX
CEF	LL	21C	C	8WREEXIT
CEF	LL	2C7	C	8ABRTSEV
CEF	LL	2C2	O	8EOFEXIT
CEF	LL	2C3	C	8ERREXIT
CEF	LL	2C4	C	8FLOVTRG
CEF	LL	2C5	C	8IOTRIO
CEF	LL	216	C	8SENLITE
CEF	LL	1FA	C	8TINIT
CEF	LL	31E	C	8ASVARTB
CEF	LL	FC8	C	7DCBSRCH
CEF	LL	217	C	8DODCBAC
CEF	LL	2CF	C	8TRUNC
CEF	LL	211	C	8FPTCHN
CEF	LL	212	C	8FPTPIR
CEF	LL	B42	C	9READ
CEF	LL	F9E	C	7EOFABRT
CEF	LL	312	C	8UNITVAL
CEF	LL	2EA	C	8TLBIT
CEF	LL	94A	C	9BEDIT
CEF	LL	2FA	C	6NRELMTS
CEF	LL	E4C	C	7IODATUM
CEF	LL	2FB	C	8IODACCR
CEF	LL	2F6	C	8IODTYPE
CEF	LL	2FC	C	8TBETA
CEF	LL	96C	C	9NOUTDEV
CEF	LL	2F4	O	8ENDIOL
CEF	LL	2F8	C	8INPTERM
CEF	LL	3CD	C	8IOENLOC
CEF	LL	25A	C	8TEDIT
CEF	LL	2EC	C	8TRNCTMF
CEF	LL	2ED	C	8TRUNK
CEF	LL	FCE	C	9DATA
CEF	LL	2F9	O	6DATLINK
CEF	LL	173	C	7ERROR
CEF	LL	310	C	8UNITNAM
CEF	LL	F84	C	7UNITAC

ORIGINAL PAGE IS OF POOR QUALITY

```
CEF LL        132 C     9BINDEC
CEF LL        C5E C     9RENTER
CEF LL        3C7 C     8EOFT
CEF LL        227 C     8ERRORT
CEF LL        215 C     8RENTBLK
CEF LL  FFFF  FFC C     8PIROFF
CEF LL        2CF C     8VARSTRT
CEF LL          7 C     8NOARGCS
CEF LL        1E4 C     7BUFOUT
CEF LL        1E2 C     7BUFOUTC
CEF LL        21A C     8TERROR
CEF LL        252 C     8TKEYWD
CEF LL        259 C     8TDIRIOT
CEF LL        253 C     8TDIRIO
CEF LL        25A C     6BINBUF
CEF LL        3C3 0     6EOFCALL
CEF LL        3C4 0     6EOFJACR
CEF LL        3C5 C     6EOFUACR
CEF LL        3C6 C     6EOFUTRG
CEF LL        2FB C     6RECSIZE
CEF LL        3C8 C     6WRECALL
CEF LL        3C9 C     6WREJACR
CEF LL        3CA C     6WREUADR
CEF LL        3CB C     6WREUTRG
CEF LL        2EE C     8OFTEMP
CEF LL        319 C     8TDUMP
CEF LL        2C2 C     8TINPLTL
CEF LL        2E8 C     8TRNCTM1
CEF LL        31C C     8DUMPT
CEF LL        3CC C     8WRET
CEF LL        3FD 0     CLS
CEF LL        5B8 C     WERROR
CEF LL        61E C     RCWD
CEF LL        59A C     CIOP
CEF LL        47A C     TCIOP
CEF LL        58E 0     WERR
CEF LL        5F7 0     ERRADD
CEF LL        5EB 0     ABNADD
CEF LL        58A C     ERTAG
CEF LL        688 C     CONSTK
CEF LL        63E C     CON
CEF LL        65F C     DISCON
CEF LL        669 C     ENDCON
PACING HAS COMPLETED

FILE  FP.FLEX          USED   280  GRANULES

FILE  BT.X1            USED     0  GRANULES

FILE  BT.X2            USED     6  GRANULES

FILE  BT.X3            USED     3  GRANULES
```

A59

ORIGINAL PAGE IS OF POOR QUALITY

```
FILE  BT,X4          USED     3  GRANULES
FILE  BT,X5          USED     8  GRANULES
FILE  BT,X6          USED     0  GRANULES

NC.OF-MAP
FIN
```

ORIGINAL PAGE IS
OF POOR QUALITY

XCS SIGM 5/7 RBM OPERATING SYSTEM ** VERSION C01 **

NAME ... .
ACCOUNT ....
TOTAL JOB TIME OCT18 C1

ORIGINAL PAGE IS
OF POOR QUALITY

```
JOB
ASSIGN ir.1800,9 A8C1
MACECII
SAVE ALL
AVE TAPE OK
REWIND 9TA8C
FIN
```

A62

ORIGINAL PAGE IS
OF POOR QUALITY

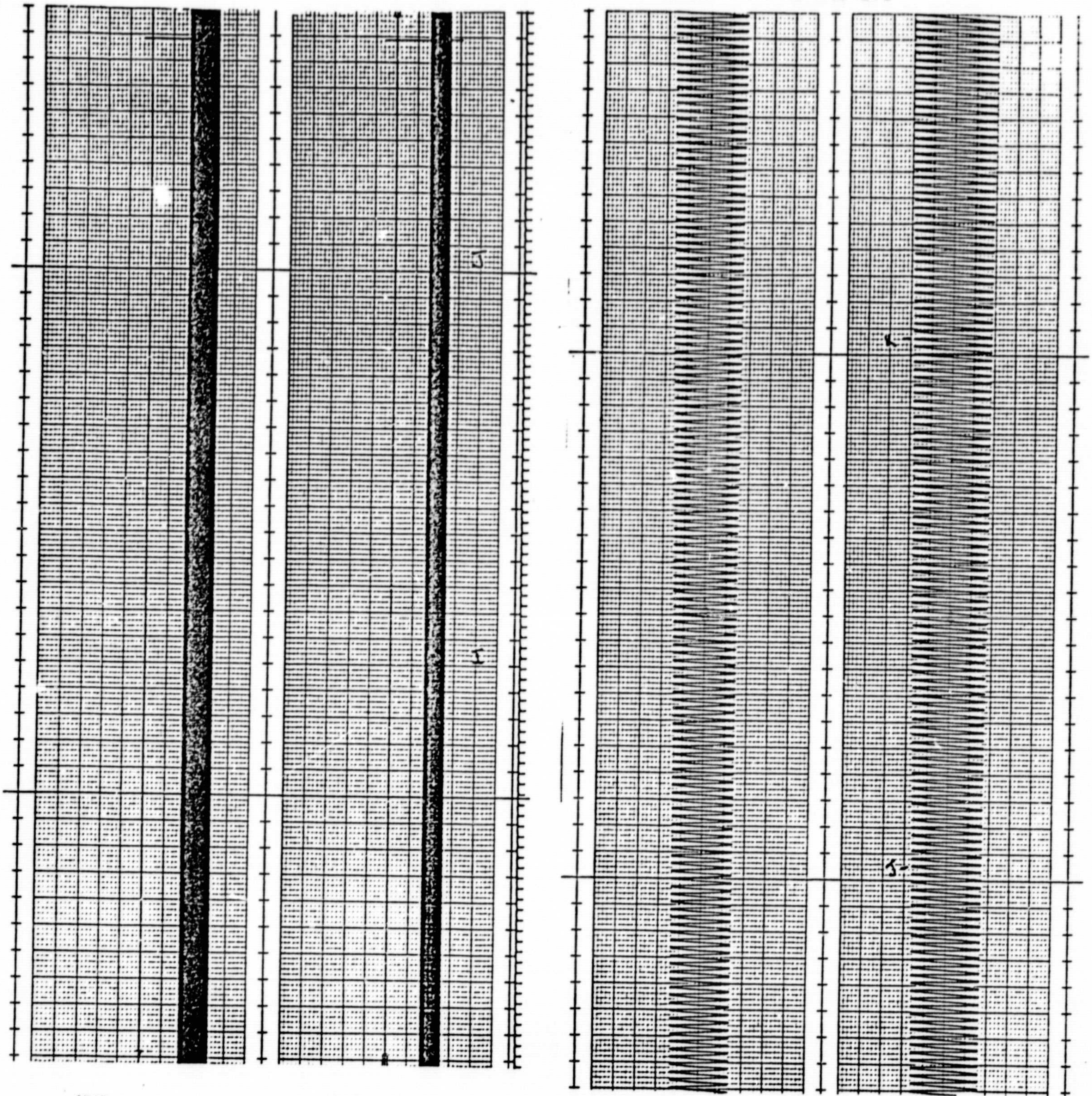
XDS SIGMA 5/7 RBM OPERATING SYSTEM ** VERSION C03 **

NAME ... .
ACCOUNT ....
TOTAL JOB TIME 00:01:37

A63

ORIGINAL PAGE IS
OF POOR QUALITY

ORIGINAL PAGE IS
OF POOR QUALITY



VWP
Channel 23

VWT
Channel 24

DEAV
Channel 11

DEAZ
Channel 12

Recorder 2
2 volts/line
.2 mm/sec

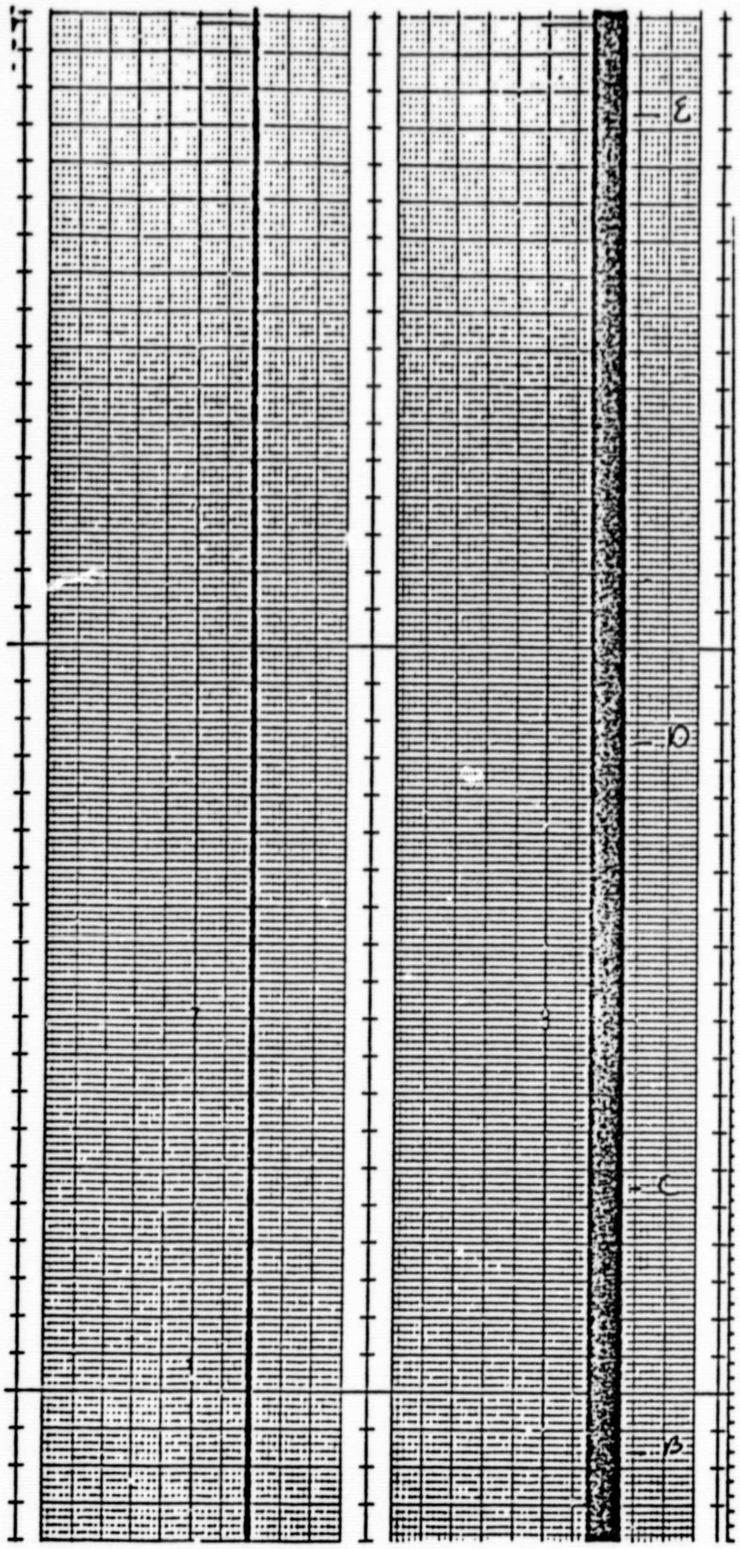
Recorder 1
5 volts/line
.5 mm/sec

SQ1C 8-18-83
SQ1 = .0022

ORIGINAL PAGE IS
OF POOR QUALITY

```
DATE  12: 6:83      TIME  10:34
 SK:
  0.0000000       0.0000000       0.0000000       0.0000000
  0.0000000       0.0000000       0.0000000       0.0000000
  2.1100000E-02   9.4349991E-04   1.4640000E-05   1.2199999E-03
 SC:
  0.0000000       0.0000000       0.0000000       0.0000000
  9.0299989E-04   3.1500000E-03   2.2789999E-03   1.8910000E-03
  0.0000000       0.0000000       0.0000000       0.0000000
 SQ:
  0.0000000       0.0000000       0.0000000       0.0000000
  0.0000000       0.0000000       0.0000000       0.0000000
  2.2000000E-03   1.5760000E-03   1.0970000E-03   9.4530010E-04
 BETA =   0.0000000
 ZER =   4.9999999E-03
 OM =   -30505.23              GAØ nominal
 ROOTS:
 -0.79935911E+02  0.44724367E+04
 -0.79935911E+02 -0.44724367E+04
 -0.27621234E+03  0.40961492E+04
 -0.27621234E+03 -0.40961492E+04
 -0.86066881E+02  0.41717931E+04
 -0.86066881E+02 -0.41717931E+04
 -0.73528848E+02  0.41043414E+04
 -0.73528848E+02 -0.41043414E+04
 -0.48516722E+03  0.34113583E+04
 -0.48516722E+03 -0.34113583E+04
 -0.33956336E+02  0.33492939E+04
 -0.33956336E+02 -0.33492939E+04
 -0.28951950E+02  0.30458877E+04
 -0.28951950E+02 -0.30458877E+04
 -0.19883520E+02  0.29396311E+04
 -0.19883520E+02 -0.29396311E+04
 -0.21216342E+02  0.27264818E+04
 -0.21216342E+02 -0.27264818E+04
 -0.25704754E+02  0.52686377E+03
 -0.25704754E+02 -0.52686377E+03
 -0.40716235E+01  0.68776275E+03
 -0.40716235E+01 -0.68776275E+03
 -0.13289674E+02  0.27566230E+03
 -0.13289674E+02 -0.27566230E+03
 -0.10169385E+02  0.22228877E+04
 -0.10169385E+02 -0.22228877E+04
 -0.83239346E+02  0.16278469E+04
 -0.83239346E+02 -0.16278469E+04
  0.56087606E+01  0.20683037E+04
  0.56087606E+01 -0.20683037E+04
 -0.21124538E+02  0.18276960E+04
 -0.21124538E+02 -0.18276960E+04
 -0.99841461E+01  0.19301467E+04
 -0.99841461E+01 -0.19301467E+04
```

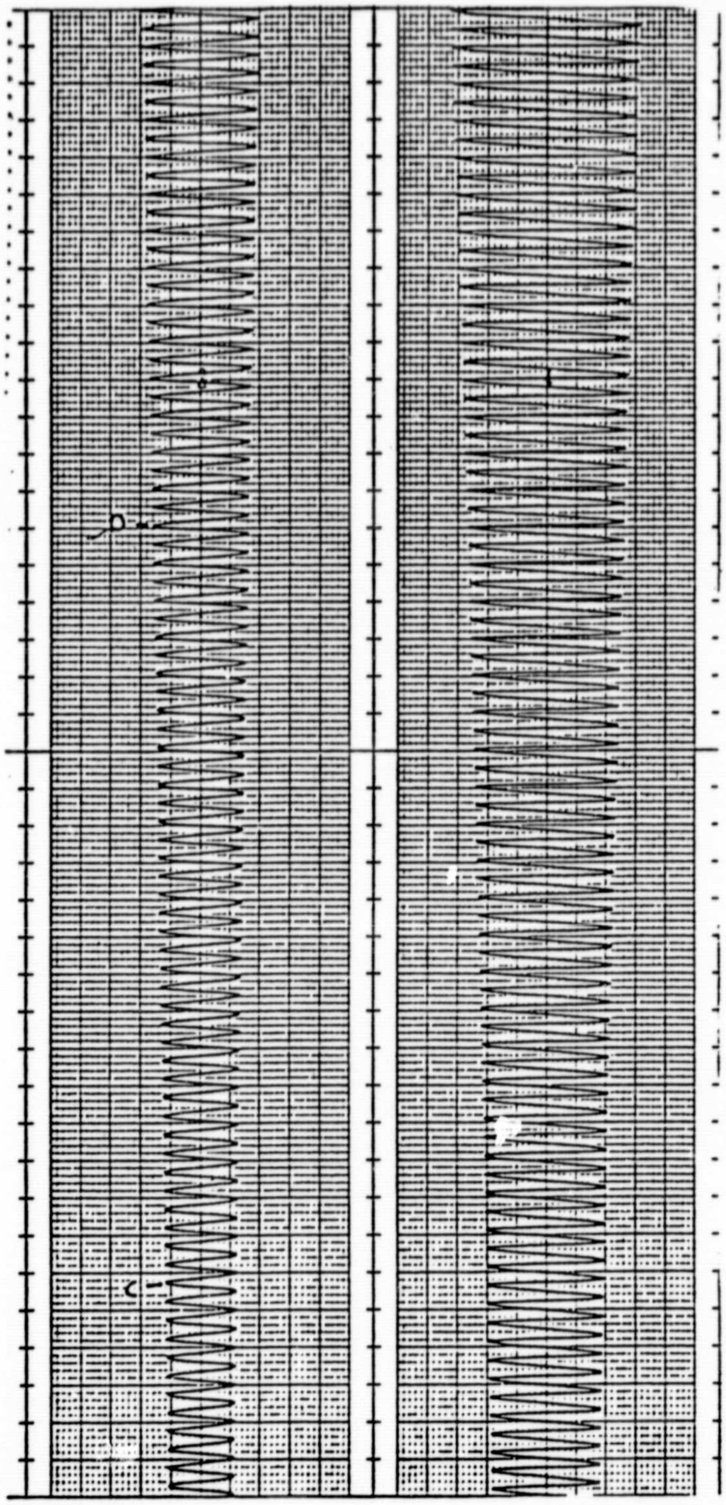
```
DATE    21: 9:84      TIME  16:13
 SK:
  0.0000000        0.0000000        0.0000000        0.0000000
  0.0000000        0.0000000        0.0000000        0.0000000
  2.1100000E-02    9.4349991E-04    1.4640000E-05    1.2159999E-03
 SC:
  0.0000000        0.0000000        0.0000000        0.0000000
  9.0299989E-04    3.1500000E-03    2.2789999E-03    1.8910000E-03
  0.0000000        0.0000000        0.0000000        0.0000000
 SB:
  0.0000000        0.0000000        0.0000000        0.0000000
  0.0000000        0.0000000        0.0000000        0.0000000
  2.2000000E-03    1.5760000E-03    1.0970000E-03    9.4530010E-04
 BETA =   0.0000000
 ZER =   4.9999999E-03
 AK:
   2750000.         2750000.         4050000.          4050000.
  -585.0540        -585.0540        -814.8732         -814.8732
  1.8237799E-02    1.8237799E-02  -6.3832283E-02   -6.3832283E-02
  9.2844002E-06    9.2844002E-06    2.9026400E-05    2.9026400E-05
 DM =    -30505.23        GAO=   0.2615050
 ROOTS:
 -0.11840662E+03   0.46422549E+04
 -0.11840662E+03  -0.46422549E+04
 -0.64050783E+02   0.41857655E+04
 -0.64050783E+02  -0.41857655E+04
 -0.64058330E+02   0.41118186E+04
 -0.64058330E+02  -0.41118186E+04
 -0.25978426E+03   0.39173275E+04
 -0.25978426E+03  -0.39173275E+04
 -0.48527661E+03   0.34111217E+04
 -0.48527661E+03  -0.34111217E+04
 -0.38991896E+02   0.33347793E+04
 -0.38991896E+02  -0.33347793E+04
 -0.29878085E+02   0.30406596E+04
 -0.29878085E+02  -0.30406596E+04
 -0.23020304E+02   0.29192285E+04
 -0.23020304E+02  -0.29192285E+04
 -0.22762785E+02   0.27265006E+04
 -0.22762785E+02  -0.27265006E+04
 -0.38109047E+01   0.68824130E+03
 -0.38109047E+01  -0.68824130E+03
 -0.25642881E+02   0.52692389E+03
 -0.25642881E+02  -0.52692389E+03
 -0.13283538E+02   0.27566540E+03
 -0.13283538E+02  -0.27566540E+03
 -0.11775142E+02   0.22175999E+04
 -0.11775142E+02  -0.22175999E+04
 -0.52755738E+02   0.17355339E+04
 -0.52755738E+02  -0.17355339E+04
 -0.49302301E+02   0.18475360E+04
 -0.49302301E+02  -0.18475360E+04
  0.34308942E+00   0.19608934E+04
  0.34308942E+00  -0.19608934E+04
 -0.44176924E+01   0.19222123E+04
 -0.44176924E+01  -0.19222123E+04
```



VUP
Channel 23

VWT
Channel 24

Recorder 2
5 volts/line
.2 mm/sec



DEAV
Channel 11

DEAZ
Channel 12

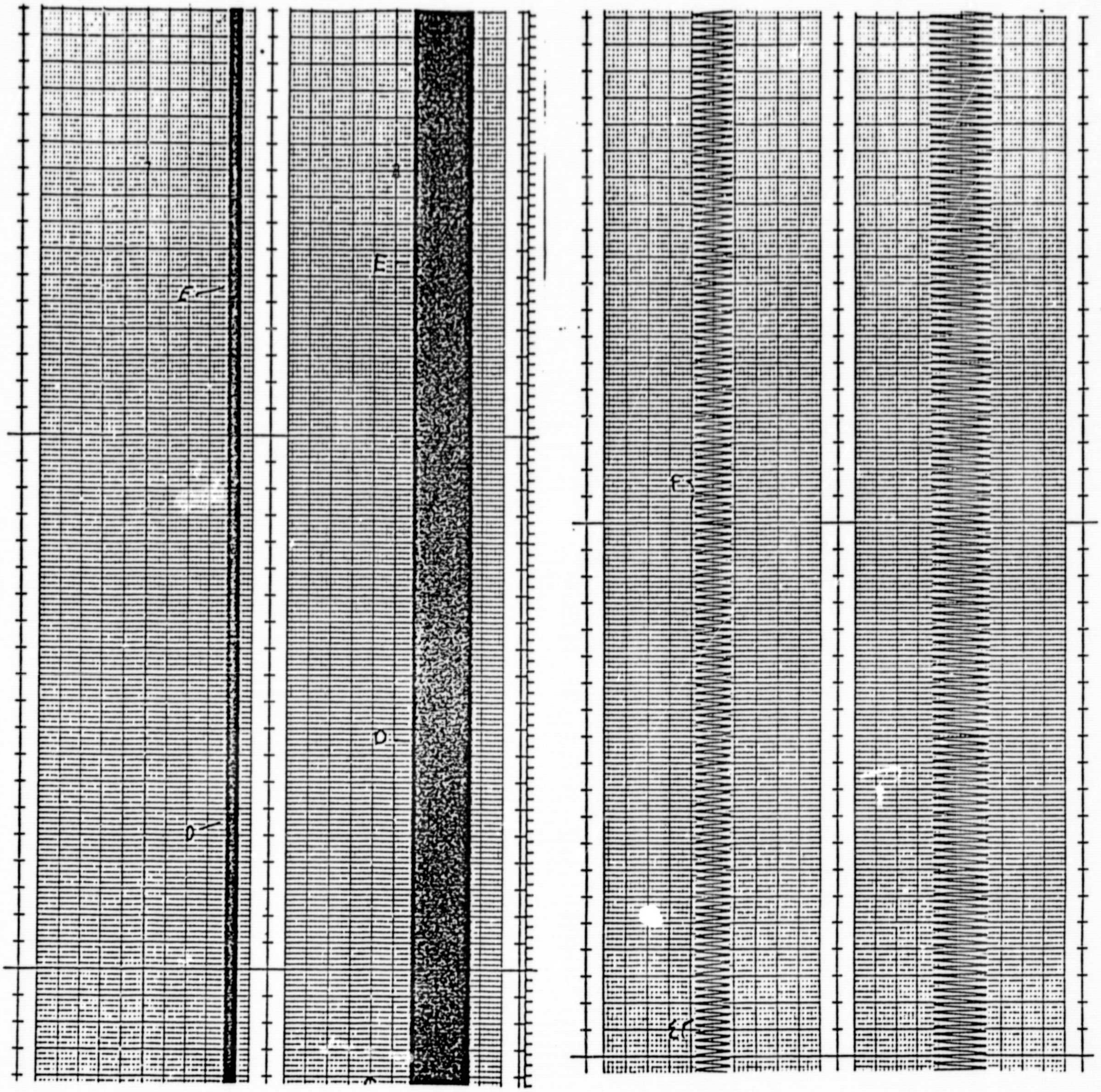
2 volts/line
.5 mm/sec

SQ2W 11-28-83
SQ2 = .005

ORIGINAL PAGE IS
OF POOR QUALITY

```
DATE    2: 9:84      TIME  15:55
 SK:
  0.0000000          0.0000000          0.0000000          0.0000000
  0.0000000          0.0000000          0.0000000          0.0000000
  2.1100000E-02     9.4349991E-04      1.4640000E-05      1.2159999E-03
 SC:
  0.0000000          0.0000000          0.0000000          0.0000000
  9.0299989E-04     3.1500000E-03      2.2789999E-03      1.8710000E-03
  0.0000000          0.0000000          0.0000000          0.0000000
 SQ:
  0.0000000          0.0000000          0.0000000          0.0000000
  0.0000000          0.0000000          0.0000000          0.0000000
  4.5100000E-04     4.9999999E-03      1.0970000E-03      9.4530010E-04
 BETA =   0.0000000
 ZER =   4.9999999E-03
 AK:
   2750000.           2750000.           4050000.           4050000.
  -585.0540          -585.0540          -814.8732          -814.8732
  1.8237799E-02     1.8237799E-02     -6.3832283E-02    -6.3832283E-02
  9.2844002E-06     9.2844002E-06      2.9026400E-05      2.9026400E-05
 DM =   -30505.23      GAØ nominal
 ROOTS:
 -0.71963374E+01   0.44789945E+04
 -0.71963374E+01  -0.44789945E+04
 -0.43978194E+03   0.41006470E+04
 -0.43978194E+03  -0.41006470E+04
  0.69280414E+00   0.41688039E+04
  0.69280414E+00  -0.41688039E+04
 -0.63169950E+02   0.41059506E+04
 -0.63169950E+02  -0.41059506E+04
 -0.48528130E+03   0.34113958E+04
 -0.48528130E+03  -0.34113958E+04
 -0.35347678E+02   0.33513754E+04
 -0.35347678E+02  -0.33513754E+04
 -0.29758403E+02   0.30460201E+04
 -0.29758403E+02  -0.30460201E+04
 -0.21983092E+02   0.29398590E+04
 -0.21983092E+02  -0.29398590E+04
 -0.22511638E+02   0.27269303E+04
 -0.22511638E+02  -0.27269303E+04
 -0.13281420E+02   0.27566187E+03
 -0.13281420E+02  -0.27566187E+03
 -0.25635004E+02   0.52684618E+03
 -0.25635004E+02  -0.52684618E+03
 -0.38795707E+01   0.68768553E+03
 -0.38795707E+01  -0.68768553E+03
 -0.11821532E+02   0.22230894E+04
 -0.11821532E+02  -0.22230894E+04
 -0.66062140E+02   0.16259648E+04
 -0.66062140E+02  -0.16259648E+04
 -0.11334726E+02   0.20678403E+04
 -0.11334726E+02  -0.20678403E+04
 -0.20224677E+02   0.12289417E+04
 -0.20224677E+02  -0.12289417E+04
 -0.10339670E+02   0.19301003E+04
 -0.10339670E+02  -0.19301003E+04
```

```
DATE   2: 9:84     TIME  15:23
 SK:
  0.0000000       0.0000000       0.0000000       0.0000000
  0.0000000       0.0000000       0.0000000       0.0000000
  2.1100000E-02   9.4349991E-04   1.4640000E-05   1.2159999E-03
 SC:
  0.0000000       0.0000000       0.0000000       0.0000000
  9.0299989E-04   3.1500000E-03   2.2789999E-03   1.8910000E-03
  0.0000000       0.0000000       0.0000000       0.0000000
 SR:
  0.0000000       0.0000000       0.0000000       0.0000000
  0.0000000       0.0000000       0.0000000       0.0000000
  4.5100000E-04   4.9999999E-03   1.0970000E-03   9.4530010E-04
 BETA =   0.0000000
 ZER =   4.9999999E-03
 AK:
   2750000.        2750000.        4050000.        4050000.
  -585.0540       -585.0540       -814.8732       -814.8732
  1.8237799E-02   1.8237799E-02  -6.3832283E-02  -6.3832283E-02
  9.2844002E-06   9.2844002E-06   2.9026400E-05   2.9026400E-05
 OM =   -30505.23        GAØ= .2615Ø5Ø
 ROOTS:
  0.45324308E+01   0.46498180E+04
  0.45324308E+01  -0.46498180E+04
 -0.32138168E+02   0.41789180E+04
 -0.32138168E+02  -0.41789180E+04
 -0.52126648E+02   0.41152282E+04
 -0.52126648E+02  -0.41152282E+04
 -0.41906351E+03   0.39180144E+04
 -0.41906351E+03  -0.39180144E+04
 -0.48590529E+03   0.34109085E+04
 -0.48590529E+03  -0.34109085E+04
 -0.42521707E+02   0.33400184E+04
 -0.42521707E+02  -0.33400184E+04
 -0.30582553E+02   0.30410829E+04
 -0.30582553E+02  -0.30410829E+04
 -0.24595551E+02   0.29200368E+04
 -0.24595551E+02  -0.29200368E+04
 -0.23949028E+02   0.27274074E+04
 -0.23949028E+02  -0.27274074E+04
 -0.25587810E+02   0.52690550E+03
 -0.25587810E+02  -0.52690550E+03
 -0.36975567E+01   0.68817632E+03
 -0.36975567E+01  -0.68817632E+03
 -0.13275979E+02   0.27566229E+03
 -0.13275979E+02  -0.27566229E+03
 -0.12095313E+02   0.22177543E+04
 -0.12095313E+02  -0.22177543E+04
 -0.43769358E+02   0.17275625E+04
 -0.43769358E+02  -0.17275625E+04
 -0.41321132E+02   0.18538065E+04
 -0.41321132E+02  -0.18538065E+04
 -0.11024915E+02   0.19633718E+04
 -0.11024915E+02  -0.19633718E+04
 -0.97683227E+01   0.19290560E+04
 -0.97683227E+01  -0.19290560E+04
```



VWP
Channel 23

VWT
Channel 24

Recorder 2
5 volts/line
.2 mm/sec

DEAV
Channel 11

DEAZ
Channel 12

Recorder 1
2 volts/line
1 mm/sec

SQ3G 9-6-83
SQ3 = .0071

ORIGINAL PAGE IS
OF POOR QUALITY

DATE 12: 5:83 TIME 14:37

SK:

0.0000000	0.0000000	0.0000000	0.0000000
0.0000000	0.0000000	0.0000000	0.0000000
2.1100000E-02	9.4349991E-04	1.4640000E-03	1.2159999E-03

SC:

0.0000000	0.0000000	0.0000000	0.0000000
9.0299989E-04	3.1500000E-03	2.2789999E-03	1.8910000E-03
0.0000000	0.0000000	0.0000000	0.0000000

SQ:

0.0000000	0.0000000	0.0000000	0.0000000
0.0000000	0.0000000	0.0000000	0.0000000
4.5100000E-04	1.5760000E-03	7.1000000E-03	9.4530010E-04

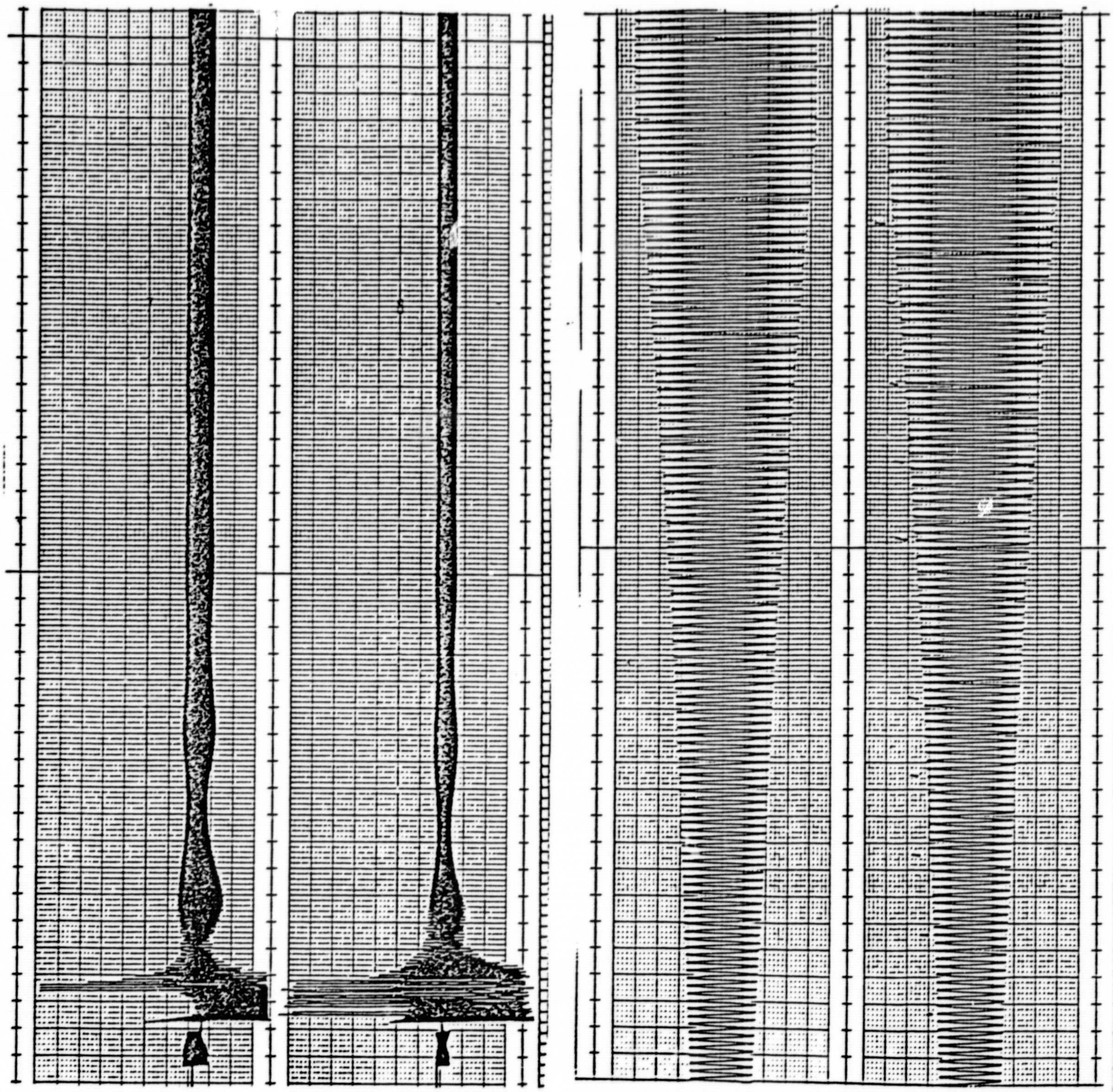
BETA = 0.0000000
ZER = 4.9999999E-03
OM = -30505.23 GAØ nominal

ROOTS:

-0.61190548E+02	0.44566587E+04
-0.61190548E+02	-0.44566587E+04
-0.32004597E+02	0.41789481E+04
-0.32004597E+02	-0.41789481E+04
-0.12195376E+03	0.41178305E+04
-0.12195376E+03	-0.41178305E+04
-0.28330611E+03	0.40916206E+04
-0.28330611E+03	-0.40916206E+04
-0.48537776E+03	0.34114238E+04
-0.48537776E+03	-0.34114238E+04
-0.35376957E+02	0.33497607E+04
-0.35376957E+02	-0.33497607E+04
-0.28873108E+02	0.30459745E+04
-0.28873108E+02	-0.30459745E+04
-0.20382432E+02	0.29398977E+04
-0.20382432E+02	-0.29398977E+04
-0.25462865E+02	0.27271358E+04
-0.25462865E+02	-0.27271358E+04
-0.25617235E+02	0.52683398E+03
-0.25617235E+02	-0.52683398E+03
-0.38369238E+01	0.68769368E+03
-0.38369238E+01	-0.68769368E+03
-0.13275129E+02	0.27565653E+03
-0.13275129E+02	-0.27565653E+03
-0.11301290E+02	0.22230739E+04
-0.11301290E+02	-0.22230739E+04
-0.82201973E+02	0.16283977E+04
-0.82201973E+02	-0.16283977E+04
-0.21592152E+02	0.18278164E+04
-0.21592152E+02	-0.18278164E+04
-0.47684300E+01	0.20683338E+04
-0.47684300E+01	-0.20683338E+04
-0.10318707E+02	0.19300590E+04
-0.10318707E+02	-0.19300590E+04

ORIGINAL PAGE IS
OF POOR QUALITY

```
DATE   2: 9:84       TIME  16:25
 SK:
  0.0000000        0.0000000        0.0000000        0.0000000
  0.0000000        0.0000000        0.0000000        0.0000000
  2.1100000E-02    9.4349991E-04    1.4640000E-03    1.2159999E-03
 SC:
  0.0000000        0.0000000        0.0000000        0.0000000
  9.0299989E-04    3.1500000E-03    2.2789999E-03    1.8710000E-03
  0.0000000        0.0000000        0.0000000        0.0000000
 SQ:
  0.0000000        0.0000000        0.0000000        0.0000000
  0.0000000        0.0000000        0.0000000        0.0000000
  4.5100000E-04    1.5760000E-03    7.1000000E-03    9.4530010E-04
 BETA =  0.0000000
 ZER =  4.9999999E-03
 AK:
   2750000.         2750000.         4050000.         4050000.
  -585.0540        -585.0540        -814.8732        -814.8732
  1.8237799E-02    1.8237799E-02  -6.3832283E-02  -6.3832283E-02
  9.2844002E-06    9.2844002E-06   2.9026400E-05   2.9026400E-05
 OM =  -30505.23       GA0=  0.2615050
 ROOTS:
 -0.11598564E+03   0.46384816E+04
 -0.11598564E+03  -0.46384816E+04
  0.99843389E-01   0.41602957E+04
  0.99843389E-01  -0.41602957E+04
 -0.12199730E+03   0.41361821E+04
 -0.12199730E+03  -0.41361821E+04
 -0.26212496E+03   0.39225237E+04
 -0.26212496E+03  -0.39225237E+04
 -0.48527950E+03   0.34111215E+04
 -0.48527950E+03  -0.34111215E+04
 -0.39719165E+02   0.33351203E+04
 -0.39719165E+02  -0.33351203E+04
 -0.29773766E+02   0.30406645E+04
 -0.29773766E+02  -0.30406645E+04
 -0.23175104E+02   0.29193743E+04
 -0.23175104E+02  -0.29193743E+04
 -0.25591165E+02   0.27274124E+04
 -0.25591165E+02  -0.27274124E+04
 -0.37115419E+01   0.68817047E+03
 -0.37115419E+01  -0.68817047E+03
 -0.25593602E+02   0.52690164E+03
 -0.25593602E+02  -0.52690164E+03
 -0.13276052E+02   0.27566200E+03
 -0.13276052E+02  -0.27566200E+03
 -0.11981284E+02   0.22176855E+04
 -0.11981284E+02  -0.22176855E+04
 -0.49996020E+02   0.17333496E+04
 -0.49996020E+02  -0.17333496E+04
 -0.47747281E+02   0.18501680E+04
 -0.47747281E+02  -0.18501680E+04
 -0.42726250E+01   0.19627355E+04
 -0.42726250E+01  -0.19627355E+04
 -0.67806052E+01   0.19210652E+04
 -0.67806052E+01  -0.19210652E+04
```



VWP
Channel 23

VWT
Channel 24

DEAV
Channel 11

DEAZ
Channel 12

Recorder 2
2 volts/line
.2 mm/sec

Recorder 1
5 volts/line
.5 mm/sec

ORIGINAL PAGE IS
OF POOR QUALITY

SQA1 2-22-84
SQA = .0019

```
DATE   1:12:84      TIME   8:40
 SK:
  0.0000000       0.0000000       0.0000000       0.0000000
  0.0000000       0.0000000       0.0000000       0.0000000
  2.1100000E-02   9.4349991E-04   1.4640000E-05   1.2159999E-03
 SC:
  0.0000000       0.0000000       0.0000000       0.0000000
  9.0299989E-04   3.1500000E-03   2.2789999E-03   1.8910000E-03
  0.0000000       0.0000000       0.0000000       0.0000000
 SB:
  0.0000000       0.0000000       0.0000000       0.0000000
  0.0000000       0.0000000       0.0000000       0.0000000
  4.5100000E-04   1.5760000E-03   1.0970000E-03   1.9000000E-03
 BETA =  0.0000000
 ZER =  4.9999999E-03
 AK:
   2750000.        2750000.        4050000.        4050000.
  -585.0540       -585.0540       -814.8732       -814.8732
  1.8237799E-02   1.8237799E-02  -6.3832283E-02  -6.3832283E-02
  9.2844002E-06   9.2844002E-06   2.9026400E-05   2.9026400E-05
 DM =  -30505.23       GAO= -0.2615050
 ROOTS:
 -0.83157394E+02   0.44732169E+04
 -0.83157394E+02  -0.44732169E+04
 -0.27612102E+03   0.40958934E+04
 -0.27612102E+03  -0.40958934E+04
 -0.86719276E+02   0.41715129E+04
 -0.86719276E+02  -0.41715129E+04
 -0.67615247E+02   0.41041547E+04
 -0.67615247E+02  -0.41041547E+04
 -0.48521190E+03   0.34114134E+04
 -0.48521190E+03  -0.34114134E+04
 -0.34052588E+02   0.33491543E+04
 -0.34052588E+02  -0.33491543E+04
 -0.29275179E+02   0.30459018E+04
 -0.29275179E+02  -0.30459018E+04
 -0.20687711E+02   0.29396189E+04
 -0.20687711E+02  -0.29396189E+04
 -0.21575848E+02   0.27264815E+04
 -0.21575848E+02  -0.27264815E+04
 -0.40759570E+01   0.68776022E+03
 -0.40759570E+01  -0.68776022E+03
 -0.25726968E+02   0.52686981E+03
 -0.25726968E+02  -0.52686981E+03
 -0.13289069E+02   0.27566077E+03
 -0.13289069E+02  -0.27566077E+03
 -0.10155215E+02   0.22228893E+04
 -0.10155215E+02  -0.22228893E+04
 -0.87753722E+02   0.16281544E+04
 -0.87753722E+02  -0.16281544E+04
  0.90892508E+01   0.20682675E+04
  0.90892508E+01  -0.20682675E+04
 -0.20847440E+02   0.18274934E+04
 -0.20847440E+02  -0.18274934E+04
 -0.97406487E+01   0.19302002E+04
 -0.97406487E+01  -0.19302002E+04
```

ORIGINAL PAGE IS
OF POOR QUALITY

DATE 2:12:84 TIME 8:28

ORIGINAL PAGE IS OF POOR QUALITY

SK:

0.0000000	0.0000000	0.0000000	0.0000000
0.0000000	0.0000000	0.0000000	0.0000000
2.1100000E-02	9.4349991E-04	1.4640000E-05	1.2159999E-03

SC:

0.0000000	0.0000000	0.0000000	0.0000000
9.0299989E-04	3.1500000E-03	2.2789999E-03	1.8910000E-03
0.0000000	0.0000000	0.0000000	0.0000000

SQ:

0.0000000	0.0000000	0.0000000	0.0000000
0.0000000	0.0000000	0.0000000	0.0000000
4.5100000E-04	1.5760000E-03	1.0970000E-03	1.9000000E-03

BETA = 0.0000000

ZER = 4.9999999E-03

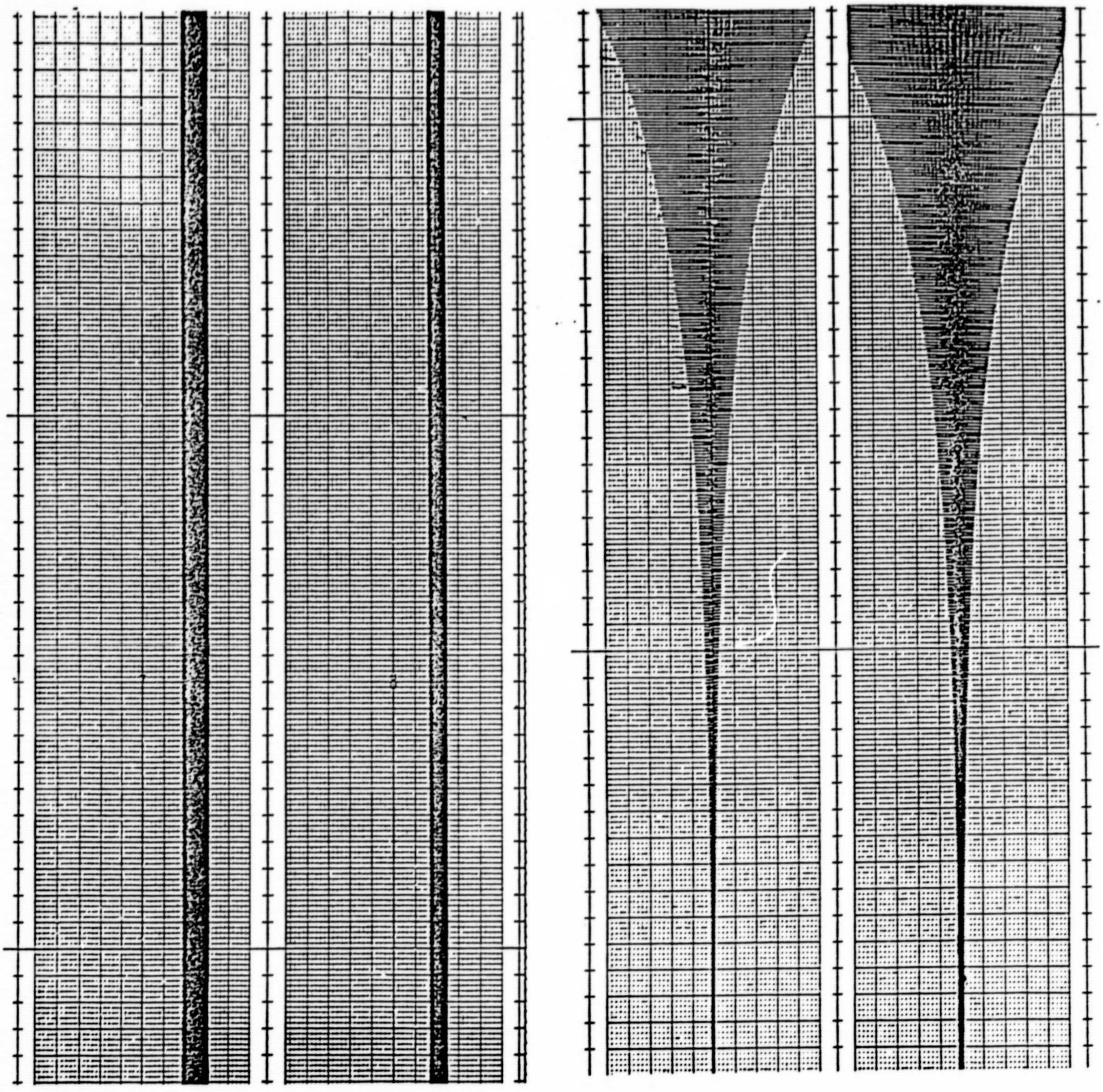
AK:

2750000.	2750000.	4050000.	4050000.
-585.0540	-585.0540	-814.8732	-814.8732
1.8237799E-02	1.8237799E-02	-6.3832283E-02	-6.3832283E-02
9.2844002E-06	9.2844002E-06	2.9026400E-05	2.9026400E-05

DM = -30505.23 GAO= 0.2615050

ROOTS:

-0.12065091E+03	0.46427846E+04
-0.12065091E+03	-0.46427846E+04
-0.63800489E+02	0.41866875E+04
-0.63800489E+02	-0.41866875E+04
-0.61776159E+02	0.41102071E+04
-0.61776159E+02	-0.41102071E+04
-0.25944503E+03	0.39174964E+04
-0.25944503E+03	-0.39174964E+04
-0.48532575E+03	0.34111149E+04
-0.48532575E+03	-0.34111149E+04
-0.39008586E+02	0.33348449E+04
-0.39008586E+02	-0.33348449E+04
-0.29928858E+02	0.30406701E+04
-0.29928858E+02	-0.30406701E+04
-0.23501313E+02	0.29192133E+04
-0.23501313E+02	-0.29192133E+04
-0.22787406E+02	0.27265944E+04
-0.22787406E+02	-0.27265944E+04
-0.38017197E+01	0.68823535E+03
-0.38017197E+01	-0.68823535E+03
-0.25652156E+02	0.52693152E+03
-0.25652156E+02	-0.52693152E+03
-0.13282031E+02	0.27566454E+03
-0.13282031E+02	-0.27566454E+03
-0.11791423E+02	0.22176370E+04
-0.11791423E+02	-0.22176370E+04
-0.55321716E+02	0.17379735E+04
-0.55321716E+02	-0.17379735E+04
-0.50376282E+02	0.18453672E+04
-0.50376282E+02	-0.18453672E+04
0.25282462E+01	0.19597019E+04
0.25282462E+01	-0.19597019E+04
-0.29737321E+01	0.19230987E+04
-0.29737321E+01	-0.19230987E+04



VWP
Channel 23

VWT
Channel 24

DEAV
Channel 11

DEAZ
Channel 12

Recorder 2
2 volts/line
.2 mm/sec

Recorder 1
2 volts/line
.2 mm/sec

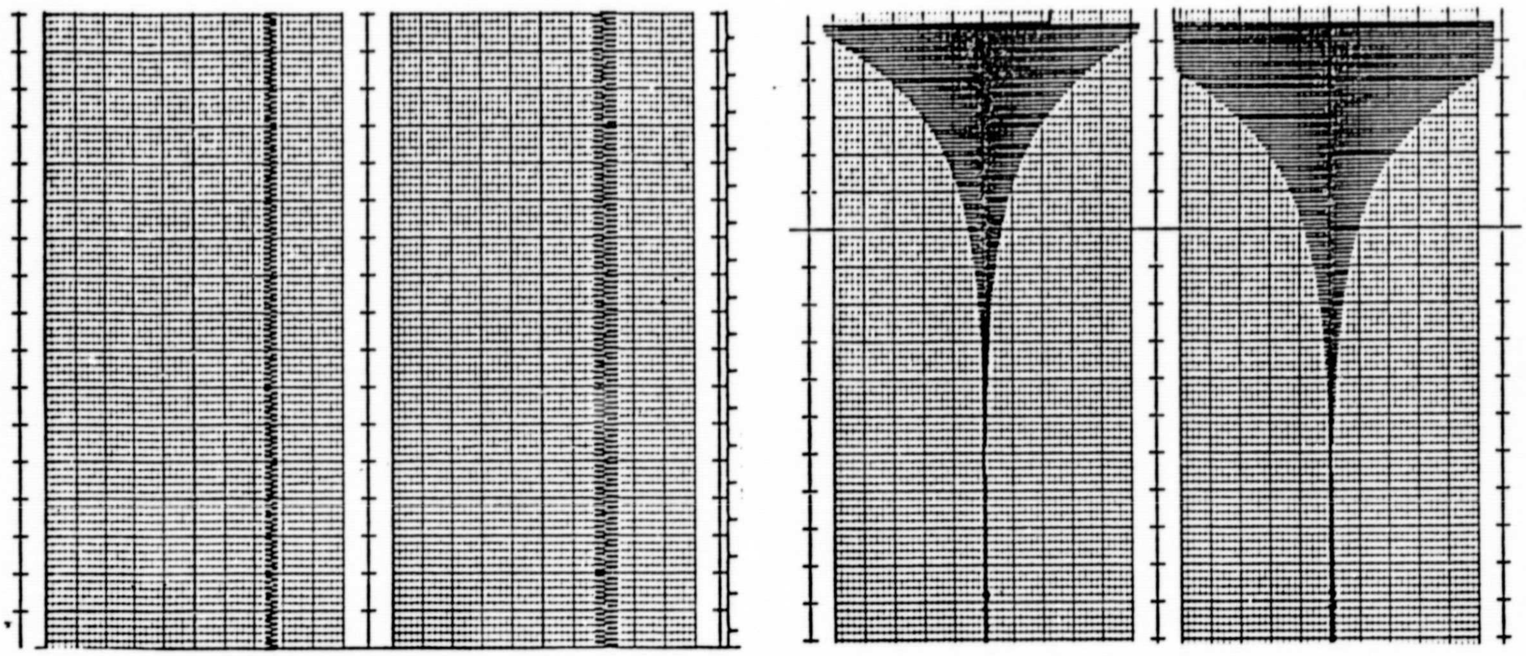
BETC 7-29-83
BETA = .5

ORIGINAL PAGE IS
OF POOR QUALITY

```
DATE   1:12:84      TIME  11:37
 SK:
  0.0000000        0.0000000        0.0000000        0.0000000
  0.0000000        0.0000000        0.0000000        0.0000000
  2.1100000E-02    9.4349991E-04    1.4640000E-05    1.2159999E-03
 SC:
  0.0000000        0.0000000        0.0000000        0.0000000
  9.0299989E-04    3.1500000E-03    2.2789999E-03    1.8910000E-03
  0.0000000        0.0000000        0.0000000        0.0000000
 SU:
  0.0000000        0.0000000        0.0000000        0.0000000
  0.0000000        0.0000000        0.0000000        0.0000000
  4.5100000E-04    1.5760000E-03    1.0970000E-03    9.4530010E-04
 BETA =  0.5000000
 ZER =  4.9999999E-03
 AK:
   2750000.         2750000.         4050000.         4050000.
   -585.0340        -585.0340        -814.8732        -814.8732
  1.8237799E-02    1.8237799E-02  -6.3832283E-02  -6.3832283E-02
  9.2844002E-06    9.2844002E-06   2.9026400E-05   2.9026400E-05
 DM =  -30505.23      GAO= -0.2615050
 ROOTS:
 -0.83139733E+02   0.44732082E+04
 -0.83139733E+02  -0.44732082E+04
 -0.27614064E+03   0.40958513E+04
 -0.27614064E+03  -0.40958513E+04
 -0.67789884E+02   0.41041544E+04
 -0.67789884E+02  -0.41041544E+04
 -0.86708192E+02   0.41715075E+04
 -0.86708192E+02  -0.41715075E+04
 -0.48513606E+03   0.34113466E+04
 -0.48513606E+03  -0.34113466E+04
 -0.34107351E+02   0.33492120E+04
 -0.34107351E+02  -0.33492120E+04
 -0.29268675E+02   0.30458913E+04
 -0.29268675E+02  -0.30458913E+04
 -0.20522242E+02   0.29396520E+04
 -0.20522242E+02  -0.29396520E+04
 -0.21529340E+02   0.27265159E+04
 -0.21529340E+02  -0.27265159E+04
 -0.40917649E+01   0.68778469E+03
 -0.40917649E+01  -0.68778469E+03
 -0.25737271E+02   0.52687870E+03
 -0.25737271E+02  -0.52687870E+03
 -0.13288658E+02   0.27565834E+03
 -0.13288658E+02  -0.27565834E+03
 -0.89780665E+02   0.16284287E+04
 -0.89780665E+02  -0.16284287E+04
 -0.10020332E+02   0.22228258E+04
 -0.10020332E+02  -0.22228258E+04
 -0.20978615E+02   0.18273094E+04
 -0.20978615E+02  -0.18273094E+04
  0.11028501E+02   0.20682831E+04
  0.11028501E+02  -0.20682831E+04
 -0.96861367E+01   0.19302226E+04
 -0.96861367E+01  -0.19302226E+04
```

ORIGINAL PAGE IS
OF POOR QUALITY

```
DATE   2:10:84        TIME  15: 0
 SK:
  0.0000000         0.0000000         0.0000000         0.0000000
  0.0000000         0.0000000         0.0000000         0.0000000
  2.1100000E-02     9.4349991E-04     1.4640000E-05     1.2159999E-03
 SC:
  0.0000000         0.0000000         0.0000000         0.0000000
  9.0299989E-04     3.1500000E-03     2.2789999E-03     1.8710000E-03
  0.0000000         0.0000000         0.0000000         0.0000000
 SQ:
  0.0000000         0.0000000         0.0000000         0.0000000
  0.0000000         0.0000000         0.0000000         0.0000000
  4.5100000E-04     1.5760000E-03     1.0970000E-03     9.4530010E-04
 BETA =   0.5000000
 ZER =  4.9999999E-03
 AK:
   2750000.          2750000.          4050000.          4050000.
  -585.0540         -585.0540         -814.8732         -814.8732
  1.8237799E-02     1.8237799E-02    -6.3832283E-02    -6.3832283E-02
  9.2844002E-06     9.2844002E-06     2.9026400E-05     2.9026400E-05
 DM =   -30505.23        GAO=  0.2615050
 ROOTS:
 -0.12060695E+03   0.46427885E+04
 -0.12060695E+03  -0.46427885E+04
 -0.63787359E+02   0.41866397E+04
 -0.63787359E+02  -0.41866397E+04
 -0.61833970E+02   0.41102093E+04
 -0.61833970E+02  -0.41102093E+04
 -0.25945198E+03   0.39175064E+04
 -0.25945198E+03  -0.39175064E+04
 -0.48517526E+03   0.34110472E+04
 -0.48517526E+03  -0.34110472E+04
 -0.39155423E+02   0.33348283E+04
 -0.39155423E+02  -0.33348283E+04
 -0.30083780E+02   0.30406558E+04
 -0.30083780E+02  -0.30406558E+04
 -0.23407803E+02   0.29192980E+04
 -0.23407803E+02  -0.29192980E+04
 -0.22788338E+02   0.27265741E+04
 -0.22788338E+02  -0.27265741E+04
 -0.38071221E+01   0.68825240E+03
 -0.38071221E+01  -0.68825240E+03
 -0.25659954E+02   0.52692533E+03
 -0.25659954E+02  -0.52692533E+03
 -0.13282979E+02   0.27566517E+03
 -0.13282979E+02  -0.27566517E+03
 -0.11759452E+02   0.22175953E+04
 -0.11759452E+02  -0.22175953E+04
 -0.56462277E+02   0.17392059E+04
 -0.56462277E+02  -0.17392059E+04
 -0.51076097E+02   0.18444605E+04
 -0.51076097E+02  -0.18444605E+04
  0.38893818E+01   0.19591666E+04
  0.38893818E+01  -0.19591666E+04
 -0.24514218E+01   0.19236479E+04
 -0.24514213E+01  -0.19236479E+04
```



VWP Channel 23	VWT Channel 24	DEAV Channel 11	DEAZ Channel 12

Recorder 2
2 volts/line
.5 mm/sec

Recorder 1
2 volts/line
.2 mm/sec

CDCZ 6-27-83
TWOZETR = .3

DATE 1:11:84 TIME 14:33

SK:

0.0000000	0.0000000	0.0000000	0.0000000
0.0000000	0.0000000	0.0000000	0.0000000
2.1100000E-02	9.4349991E-04	1.4640000E-05	1.2159999E-03

SC:

0.0000000	0.0000000	0.0000000	0.0000000
9.0299989E-04	3.1500000E-03	2.2789999E-03	1.8910000E-03
0.0000000	0.0000000	0.0000000	0.0000000

SU:

0.0000000	0.0000000	0.0000000	0.0000000
0.0000000	0.0000000	0.0000000	0.0000000
4.5100000E-04	1.5760000E-03	1.0970000E-03	9.4530010E-04

BETA = 0.0000000

ZER = 0.1500000

AK:

2750000.	2750000.	4050000.	4050000.
-585.0540	-585.0540	-814.8732	-814.8732
1.8237799E-02	1.8237799E-02	-6.3832283E-02	-6.3832283E-02
9.2844002E-06	9.2844002E-06	2.9026400E-05	2.9026400E-05

DM = -30505.23 GA0= -0.2615050

ROOTS:

-0.17861618E+03	0.44497290E+04
-0.17861618E+03	-0.44497290E+04
-0.65234460E+03	0.39851023E+04
-0.65234460E+03	-0.39851023E+04
-0.86732652E+02	0.41720853E+04
-0.86732652E+02	-0.41720853E+04
-0.11363563E+03	0.40852646E+04
-0.11363563E+03	-0.40852646E+04
-0.48800052E+03	0.34158427E+04
-0.48800052E+03	-0.34158427E+04
-0.90251597E+02	0.33632100E+04
-0.90251597E+02	-0.33632100E+04
-0.38481431E+02	0.30444089E+04
-0.38481431E+02	-0.30444089E+04
-0.56720812E+02	0.29388877E+04
-0.56720812E+02	-0.29388877E+04
-0.89112945E+02	0.27633658E+04
-0.89112945E+02	-0.27633658E+04
-0.38255270E+01	0.68775285E+03
-0.38255270E+01	-0.68775285E+03
-0.25551802E+02	0.52685899E+03
-0.25551802E+02	-0.52685899E+03
-0.13263907E+02	0.27567031E+03
-0.13263907E+02	-0.27567031E+03
-0.13229742E+02	0.22230590E+04
-0.13229742E+02	-0.22230590E+04
-0.23067424E+03	0.17158093E+04
-0.23067424E+03	-0.17158093E+04
0.63890775E+01	0.20701221E+04
0.63890775E+01	-0.20701221E+04
-0.38167225E+02	0.18073912E+04
-0.38167225E+02	-0.18073912E+04
-0.11061449E+02	0.19292136E+04
-0.11061449E+02	-0.19292136E+04

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DATE 2:11:84 TIME 14:42

SK:

0.0000000	0.0000000	0.0000000	0.0000000
0.0000000	0.0000000	0.0000000	0.0000000
2.1100000E-02	9.4349991E-04	1.4640000E-05	1.2159999E-03

SC:

0.0000000	0.0000000	0.0000000	0.0000000
9.0299989E-04	3.1500000E-03	2.2789999E-03	1.8910000E-03
0.0000000	0.0000000	0.0000000	0.0000000

SQ:

0.0000000	0.0000000	0.0000000	0.0000000
0.0000000	0.0000000	0.0000000	0.0000000
4.5100000E-04	1.5760000E-03	1.0970000E-03	9.4530010E-04

BETA = 0.0000000

ZER = 0.1500000

AK:

2750000.	2750000.	4050000.	4050000.
-585.0540	-585.0540	-814.8732	-814.8732
1.8237799E-02	1.8237799E-02	-6.3832283E-02	-6.3832283E-02
9.2844002E-06	9.2844002E-06	2.9026400E-05	2.9026400E-05

DM = -30505.23 GAO= 0.2615050

ROOTS:

-0.22141726E+03	0.46261491E+04
-0.22141726E+03	-0.46261491E+04
-0.68195993E+02	0.41640781E+04
-0.68195993E+02	-0.41640781E+04
-0.11707120E+03	0.41090889E+04
-0.11707120E+03	-0.41090889E+04
-0.62504782E+03	0.37463908E+04
-0.62504782E+03	-0.37463908E+04
-0.48920350E+03	0.34196545E+04
-0.48920350E+03	-0.34196545E+04
-0.11577530E+03	0.33658217E+04
-0.11577530E+03	-0.33658217E+04
-0.43697916E+02	0.30371008E+04
-0.43697916E+02	-0.30371008E+04
-0.99034129E+02	0.29345480E+04
-0.99034129E+02	-0.29345480E+04
-0.71740811E+02	0.27842621E+04
-0.71740811E+02	-0.27842621E+04
-0.25631734E+02	0.52691253E+03
-0.25631734E+02	-0.52691253E+03
-0.37247203E+01	0.68815943E+03
-0.37247203E+01	-0.68815943E+03
-0.13287989E+02	0.27567622E+03
-0.13287989E+02	-0.27567622E+03
-0.16912758E+02	0.22178581E+04
-0.16912758E+02	-0.22178581E+04
-0.31916596E+02	0.17745180E+04
-0.31916596E+02	-0.17745180E+04
-0.19108209E+03	0.18841898E+04
-0.19108209E+03	-0.18841898E+04
0.15022464E+02	0.19575421E+04
0.15022464E+02	-0.19575421E+04
-0.45250241E+01	0.19258700E+04
-0.45250241E+01	-0.19258700E+04

APPENDIX C FOURIER FILTER FORTRAN CODE

```
C
C       DP1:BFFIL.FOR            JANUARY 16,1984          15:00
C
C       FOURIER TRANSFORM FILTER FOR HYBRID SIMULATION SIMULATION
C
C
C       INPUT VARIABLES:
C         FILFRE          Filter frequency
C         FREINT          Frequency interval
C         DT              Simulation time step
C         TFINAL          Stop time
C         NPTS            Number of simulation points to consider
C         RNFIN           Number of Fourier intervals to consider
C         ISPT            Sample every ISPT points
C         NPTPLT          Plot every NPTPLT points
C         JN              Joint number
C
C       INTERMEDIATE VARIABLES:
C         NN              Number of points in Fourier interval
C         KPRIME          FILFRE wavenumber
C         K1              First wavenumber of frequency band
C         KF              Last wavenumber of frequency band
C         OMEGAK(9)       Fundamental frequency for each K value
C         COS1K(9)        Cosine of OMEGAK
C         SIN1K(9)        Sine of OMEGAK
C         T0              Initial time of simulation data
C         IPT             Number of data points used
C         IPTPLT          Plot point counter
C         JPT             F0 counter
C         IPLPT           Number of plot points
C
C       OUTPUT VARIABLES:
C         T               Time
C         AK(9)           Fourier coefficients
C         BK(9)           Fourier coefficients
C         RMAG(9)         Magnitude of AK and BK
C
#EMA F
      DIMENSION AK(9),BK(9),OMEGAK(9),RMAG(9),F(5200)
      DIMENSION COS1K(9),SIN1K(9)
      CHARACTER*21 IFMT
C
C Accept parameters from terminal
C
      WRITE(7,*) 'Input frequency of interest (rad/sec)'
      READ(5,*) FILFRE
      WRITE(7,*) 'Input frequency interval'
      READ(5,*) FREINT
      WRITE(7,*) 'Input simulation time interval'
      READ(5,*) DT
      WRITE(7,*) 'Input final time'
      READ(5,*) TFINAL
      WRITE(7,*) 'Input number of points to consider'
      READ(5,*) NPTS
      WRITE(7,*) 'Input number of Fourier intervals to consider'
      READ(5,*) RNFIN
```

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```
      WRITE(7,*) 'Sample every n points; input n'
      READ(5,*) ISPT
      WRITE(7,*) 'Input points/plot'
      READ(5,*) NPTPLT
      WRITE(7,*) 'Input joint number of displacements'
      READ(5,*) JN
C
C  Set up variable format statement to read every ISPT points
C
      IF(ISPT.EQ.1) THEN
       WRITE(IFMT,8000) JN*11
C
      ELSE
       WRITE(IFMT,7000) ISPT-1,JN*11
      ENDIF
7000  FORMAT('(',I3,'(/),',I3,'X,E11.4)')
8000  FORMAT('(',I3,'X,E11.4)')
C
C  Compute filter time interval
C
      DT = DT*ISPT
C
C  Open file where initial time and DELY data are stored
C
      OPEN (UNIT=10,FILE='HYB1.DAT',STATUS='OLD',FORM='FORMATTED')
C
C  Open files to send plotting data
C
      OPEN (UNIT=13,FILE='BFFIL1.DAT',FORM='FORMATTED')
      OPEN (UNIT=15,FILE='BFFIL3.DAT',FORM='FORMATTED')
      OPEN (UNIT=17,FILE='BFFIL5.DAT',FORM='FORMATTED')
C
C  Calculate number of points necessary for each Fourier period and
C   frequency interval
C
      NN=IFIX(.5+2.*3.14159265/(DT*FREINT))
      FREINT=2.*3.14159265/(NN*DT)
      ITEMP=IFIX(RNFIN*NN)
      IF(ITEMP.LT.NPTS) NPTS=ITEMP
      IF(NN.LE.5200) GOTO 70
       WRITE(7,*) 'Number of points in Fourier interval is greater than'
       WRITE(7,*) 'dimension of F; NN=',NN
       STOP
C
C  Determine K values for region of interest
C  Dimensions of AK,BK,OMEGAK,RMAG,COS1K, and SIN1K must be changed if
C   number of K's is increased
C
70    KPRIME=IFIX(.5+FILFRE/FREINT)
      K1=KPRIME-4
      NK=9
      IF(K1.GT.0)GOTO 80
       K1=1
       NK=KF-K1+1
80    KF=KPRIME+4
C
```

```
C  Zero arrays; calculate constants for each frequency
C
      J=1
      DO 10 K=K1,KF
        OMEGAK(J)=FLOAT(K)*FREINT
        COS1K(J)=COS(OMEGAK(J)*DT)
        SIN1K(J)=SIN(OMEGAK(J)*DT)
        AK(J)=0.
        BK(J)=0.
10      J=J+1
C
C  Initialize time, point counter, plot counter, and F0 pointer
C
      READ(10,1000) T
      T0=T
      IPT=1
      IPTPLT=NPTPLT
      IPLPT=0
      JPT=1
C
C  Main loop
C
100   CONTINUE
C
C  Read DELY = F(n+1)
C
      READ(10,IFMT) FNP1
C
C  Adjust counter to proper F0, get F0 and replace with F(n+1)
C
      IF(JPT.GT.(NN+1)) JPT=JPT-NN-1
      F0=F(JPT)
      F(JPT)=FNP1
C
C  Calculate coefficients
C
      J=1
      DO 30 K=K1,KF
        TEMP1=AK(J)*SIN1K(J)
        AK(J)=AK(J)*COS1K(J)+BK(J)*SIN1K(J)-F0*COS1K(J)+FNP1
        BK(J)=F0*SIN1K(J)-TEMP1+BK(J)*COS1K(J)
        RMAG(J)=SQRT(AK(J)**2+BK(J)**2)
30      J=J+1
C
C  Test for output conditions, write time and coefficients to files,
C   increase plot counter
C
      IF(IPTPLT.NE.NPTPLT) GOTO 90
       WRITE(13,3000) T,(AK(J),J=1,nk)
       WRITE(15,3000) T,(BK(J),J=1,nk)
       WRITE(17,3000) T,(RMAG(J),J=1,nk)
       IPTPLT=0
       IPLPT=IPLPT+1
90     IPTPLT=IPTPLT+1
C
C  Check termination conditions
```

```
      IF((T.GE.TFINAL).OR.(IPT.GE.NPTS)) GOTO 50
C
C  Increment time and point counters
C
       T=T+DT
       IPT=IPT+1
       JPT=JPT+1
       GOTO 100
50    CONTINUE
C
C  Close output files
C
       CLOSE(UNIT=10)
       CLOSE(UNIT=13)
       CLOSE(UNIT=15)
       CLOSE(UNIT=17)
C
C  Open files for plotting data
C
      OPEN (UNIT=14,FILE='BFFIL2.DAT')
      OPEN (UNIT=16,FILE='BFFIL4.DAT')
      OPEN (UNIT=18,FILE='BFFIL6.DAT')
C
C  Send number of points and variables to plotting files
C
      WRITE(14,5000) 10,IPLPT
      WRITE(16,5000) 10,IPLPT
      WRITE(18,5000) 10,IPLPT
C
C  Write titles for plots
C
      WRITE(14,6000) 'TIME'
      WRITE(16,6000) 'TIME'
      WRITE(18,6000) 'TIME'

      WRITE(14,6000) 'AK(1)'
      WRITE(14,6000) 'AK(2)'
      WRITE(14,6000) 'AK(3)'
      WRITE(14,6000) 'AK(4)'
      WRITE(14,6000) 'AK(5)'
      WRITE(14,6000) 'AK(6)'
      WRITE(14,6000) 'AK(7)'
      WRITE(14,6000) 'AK(8)'
      WRITE(14,6000) 'AK(9)'

      WRITE(16,6000) 'BK(1)'
      WRITE(16,6000) 'BK(2)'
      WRITE(16,6000) 'BK(3)'
      WRITE(16,6000) 'BK(4)'
      WRITE(16,6000) 'BK(5)'
      WRITE(16,6000) 'BK(6)'
      WRITE(16,6000) 'BK(7)'
      WRITE(16,6000) 'BK(8)'
      WRITE(16,6000) 'BK(9)'
```

```
      WRITE(18,6000) 'RMAG(1)'
      WRITE(18,6000) 'RMAG(2)'
      WRITE(18,6000) 'RMAG(3)'
      WRITE(18,6000) 'RMAG(4)'
      WRITE(18,6000) 'RMAG(5)'
      WRITE(18,6000) 'RMAG(6)'
      WRITE(18,6000) 'RMAG(7)'
      WRITE(18,6000) 'RMAG(8)'
      WRITE(18,6000) 'RMAG(9)'
C
C  Close plotting files
C
      CLOSE(UNIT=14)
      CLOSE(UNIT=16)
      CLOSE(UNIT=18)
C
C  Write parameters to file
C
      OPEN(UNIT=19,FILE='BFFILP.DAT')
      WRITE(19,*) '      NN :',NN
      WRITE(19,*) '      DT :',DT
      WRITE(19,*) '      FILTER FREQUENCY :',FILFRE
      WRITE(19,*) '      FREQUENCY INTERVAL :',FREINT
      WRITE(19,*) '      DATA GOOD AT T=',T0 + DT*FLOAT(NN)
      WRITE(19,*) '      JOINT NUMBER :',JN
      WRITE(19,*)
      WRITE(19,*) '        FCN      K           OMEGAK'
      WRITE(19,*)
      J=1
      DO 40 K=K1,KF
        WRITE(19,2000) J,K,OMEGAK(J)
 40     J=J+1
      CLOSE(UNIT=19)
C
C  Format statements
C
1000  FORMAT(E11.4)
7000  FORMAT(10E11.4)
5000  FORMAT(2I5)
2000  FORMAT(8X,I2,4X,I4,8X,F11.3)
6000  FORMAT(A8)
      END
```

APPENDIX D

HYBRID SIMULATION VARIABLES

The need for better documentation became apparent when we began to study the hybrid simulation code in depth. An outdated list of variables was expanded (Appendix D), a list of comparable stability model variables compiled (Appendix E), and a comparison list made (Appendix F). These lists are not meant to be totally inclusive in themselves but provide brief descriptions of the important variables and some minor ones.

Where there is a common variable at each of the seven interaction joints it is listed as VAR(P-S3), where VAR represents the part of the variable in common. For example, the variable listed DEL(P-S3)(Y,Z) includes DELPY, DELPZ, DELTY, DELTZ, . . . for P, T, B, A, S1, S2, and S3 interaction joints (see Figure 4, Section 2.3).

HYBRID SIMULATION VARIABLES

Description	Simulation Variable
Case accelerometer outputs	A(1-7)
Accelerometer modal coefficient	AC(1-7)
Balance piston damping curvefit coefficients	ACB(0,1,2)
Balance piston spring curvefit coefficients	AKB(0,1,2)
Bearing or bearing + carrier (dependent on IBSEPBC) stiffness coefficients between deadbands	AK(P,T)(Y,Z)
Curve fit coefficients for AK(P,T)(Y,Z)	AK(P,T)(Y,Z)(0-4)
Bearing stiffness coefficients inside deadbands	AK(P,T)DB(Y,Z)
Bearing stiffness coefficients outside deadbands	AKP(P,T)(Y,Z)
Principal inertia about (X,Y,Z) axis for Jth rotor joint	AIR(1,2,3)(J)
Mass of Jth rotor joint	AMR(J)
Type of pump for output only	APUMP
Scale factor for Alford cross-coupling coefficient	BETA
Stiffness of backup structure at bearings	BK(P,T)(Y,Z)
Buffers to hold channel outputs	BUFFR(A,B)
Damping coefficients	C(B,SA,S1,S2,S3)
Squeeze film damper coefficient	C(1,2,3)
Squeeze film damper coefficient	C(1,2,3)(P,T)
Bearing damping coefficients between deadbands	C(P,T)(Y,Z)
Bearing damping coefficients outside deadbands	CP(P,T)(Y,Z)
Bearing damping coefficients inside deadbands	C(P,T)DB(Y,Z)
Multiplication matrix for deflections at Jth accelerometers	CAC(1-7)(J)
GP(P,T) - G(P,T) constant	CL(P,T)

HYBRID SIMULATION VARIABLES, con't

Description	Simulation Variable
Center of mass location	CM
Cos(PHIX)	CX
Output to channel I	DA1(I)
Maximum value during data sampling for channel I	DA1MAX(I)
Minimum value during data sampling for channel I	DA1MIN(I)
Average DA1MIN over data gathering interval	DA1MNAVG(I)
Average DA1MAX over data gathering interval	DA1MXAVG(I)
Entire selection of output values	DAC
Accelerometer position relative to joint J	DAC(1-7)(J)
Derivative of DPP	DDPP(P,T)(Y,Z)
Absolute magnitude of DEL	DEL(P,T,A,S1,S2,S3)
Relative displacement from centerline between rotor and case	DEL(P-S3)(Y,Z)
DEL in X direction at balance pistons	DELBX
Derivative of DEL	DELD(P-S3)(Y,Z)
Derivative of DELBX	DELDBX
Derivative of DELP	DELDP(P,T)(Y,Z)
DEL between inner and outer deadbands	DELP(P,T)(Y,Z)
DEL with outer deadband removed	DPP(P,T)(Y,Z)
Maximum dimension considered to be zero	DMIN
Determines PHIDDX for ramp runs	DSPEED
Integration time step	DT
DT/2	DT02
DT**2/4	DT04
Program default DT	DT2M15
Input length for calculating C(1,2,3)(P,T)	EL(P,T)

Description	Simulation Variable
Time elapsed while gathering data	ELAPTIME
C3(P,T)**2	ELOD2(P,T)
Pump and turbine max forces when cavitation is used	EMAX(P,T)
Normalized case bending modal displacement and derivatives	ETA,ETAD,ETADD(J)
ETA,ETAD,ETADD of T - DT	ETAB,ETADB,ETADDB(J)
Not used	ETABB,ETADBB, ETADDBB(J)
Rotor forces except imbalances	F(P-S3)(Y,Z)
Rotor axial force	FBX
Force used on line 734	FCAP(P,T)(Y,Z)
Case mode normalized translation	FEEC(I,J,K)
Rotor mode normalized translation	FEER(I,J,K)
Total forces applied to rotor	FR(P-S3)(Y,Z)
Maximum stiction level at S1	FS1MAX
Bearing squeeze film forces	FSF(P,T)(Y,Z)
Pump imbalance forces	FU(P-S3)(Y,Z)
Rotor modal mass integrals	GAM(0,1)
Pump bearing clearances	GP,GPP
Turbine bearing clearances	GT,GPT
Factor for DSPEED	GSPEED
Modal mass integral	I(1,2)
Logical variable indicating position of switch to reverse spin speed derivative	IBACK
Flag: if = 1, "stiffness constants for bearings and their respective carriers are to be considered independently" ; if = 0 , dependent	IBSEPBC
Case connection indices	IC(P-S3)

HYBRID SIMULATION VARIABLES, con't

Description	Simulation Variable
Squeeze film damping flag (0=none,1=cavit,2=non-cavit)	ICAV
Name and dimensions of channel assignments	ICARD(I,J)
Switch position for updating files	ICARDS
Provision for modifying channel assignments	ICHNNL(K)
Switch position to exit program	IEXIT
Flag to indicate inclusion of bending modes	IFLEX
Switch position for gathering output to line printer	IGATHER
Maximum number of passes before buffout	IMAX
IMAX x 10	IMAX10
Index for output to tape DAC channel	IOUT(K)
Rotor connection indices	IR(P-S3)
Logical variable indicating position of switch for run time input	IREMOD
Flag to signal Seal 3 inclusion	IRS3
Switch number of ITAPE	ISLTAP
Switch position for tape update	ITAPE
Sideload flag (-1=zero,1=recalculated,0=unchanged)	ISIDEL
Marder data word	IWORD
Joint locations for accelerometers	JAC(1-7)
Number of case joints	JNTC
Number of rotor joints	JNTR
Flag to indicate update data case	JREMOD
Stiffness coefficients	K(B,A,S1,S2,S3)
Bearing stiffness coefficients between deadbands	K(P,T)(Y,Z)
Number of data minus one to be output to tape	KCHAN
Bearing stiffness coefficients outside deadbands	KP(P,T)(Y,Z)

HYBRID SIMULATION VARIABLES, con't

Description	Simulation Variable
No of passes (integration steps) during data collection	KGPASS
Flag: 1 invalid case; 2 HPFTP with PHIX>0; 3 HPOTP with PHIX<0	KPUMP
Position of interaction joints along rotor	L(P,T,A,B,S1,S2,S3)
Position from center of mass along rotor in x direction of joint J	LR(J)
Total mass of rotor	M
Maximum no of int. steps while collecting data	MAXGPASS
Number of case modes	MODC
Number of rotor modes	MODR
Max number of passes before buff-out occurs	NMAX
Number of passes	NPASS
Run number	NUMRUN
Case mode natural frequency of Kth mode	OHMC(K)
OHMC(K)**2	OHMCSQ
Rotor mode natural frequency	OHMR
OHMR**2	OHMRSQ
Rigid rotor rotation	PHI(X,Y,Z)
Case mode shape translations (before assignments)	PHIC
Case mode shape translations	PHIC(P-S3)(Y,Z)
Case mode shape translations	PHIC(P,T,B)X
Rigid rotor angular velocity	PHID(X,Y,Z)
PHID of T - DT	PHID(X,Y,Z)B
Rigid rotor angular acceleration	PHIDD(X,Y,Z)
PHIDD of T - DT	PHIDD(X,Y,Z)B
Absolute value of PHIDX	PHIDXA

HYBRID SIMULATION VARIABLES, con't

Description	Simulation Variable
PHIDX**2	PHIDXSQ
Rotor mode shapes before assignments	PHIR
Rotor mode shapes	PHIR(P-S3)
$\pi/2$	PI2
Squeeze film damping coefficients	PSF(P,T)
Rigid rotor modal rotation	PSI(X,Y,Z)
Local rigid case modal rotation	PSIC(A,B)X
Cross coupling coefficients	Q(A,SA,S1,S2,S3)
Alford force cross-coupling curve fit coefficients	QA(0-4)
X axis location of Jth joint	R(J)
Squeeze film damper parameter	R(P,T)
FS1/FS1MAX	RS7
Seal damping curvefit coefficients	SC(A,1,2,3)(0,1,2)
Scale of Kth recorder channel	SCALE(K)
Full scale of Kth recorder channel	SFI(K)
Seal spring curvefit coefficients	SK(A,1,2,3)(0,1,2)
Sideload coefficients for straight line 7 segment curve fit at balance pistons	SL(Y,Z)
SL at seals	SL(A,S1,S2,S3)(Y,Z)
Sideload force factors (dependent on ISIDEL) at balance pistons	SLK
SLK at seals	
Sideload forces at balance piston	SL(Y,Z)0
SLO at seals	SL(A,S1,S2,S3)(Y,Z)0
Switch number for runtime input	SLRMOD
Intermediate coefficients in computation of sideload forces	SL(Y,Z)T SL(A,S1,S2,S3)(Y,Z)T

HYBRID SIMULATION VARIABLES, con't

Description	Simulation Variable
Rotor speed time line factor	SPEED(K)
Seal cross-coupling curvefit coefficients	SQ(A,1,2,3)(0,1,2)
SIN(PHIX)	SX
Sum of torques acting on rotor	TAUM
Intermediate sideload factor	TEMP
Final time	TF
Direction of sideload forces	THSL
Direction of sideload forces	THSL(A,S1,S2,S3)
Sideload phase angle	THSLOS
Rotor speed time line factor	TIME(K)
Rotor speed at Kth mode	TPHIDX(K)
Tic mark spacing	TPULSE
2*DT; increment for speed reversal (IBACK)	TWODT
Damping coefficient of case mode K	TWOZETC(K)
Damping coefficient of rotor mode	TWOZETR
(GP(P,T) - G(P,T))/DEL(P,T)	U(P,T)
Fluid viscosity for squeeze film damping coefficients	UM(P,T)
Rotor imbalance moments	UM(P,T,B,A,1,2,3)(Y,Z)
(DEL(P,T) - GP(P,T))/DEL(P,T)	UP(P,T)
Whirl orbital angular velocities	VW(T,P)
Rotor center of mass X displacement and derivatives	X,XD,XDD
XD,XDD of T-DT	XDB,XDDB
Nominal units/line on recorder	XF1
Rotor coulomb friction model denominator minimum velocity	XIDO
ABS(XTEMP)/ XIDO	XIDMAG

APPENDIX E

STABILITY MODEL VARIABLES

Description	Stability Model Variable
Balance piston damping curvefit coefficients	ACB
Curvefit coefficients for bearing/turbine force curve	AK
Balance piston stiffness curvefit coefficients	AKB
Absolute value of OM	AOM
AOM to the 0,1,2,3,4 powers	AOMP
Scale factor for Alford cross-coupling coefficient	BETA
Pump bearing damping	C1
Turbine bearing damping	C2
Modal damping matrix	CMAT
Array of damping matrices at 7 joints	CS
Rotor modal mass integrals	GA0,GA1
Modal mass integral constants	I1,I2
Stiffness of backup structure at bearings	KBUP,KBUT
Modal stiffness matrix	KMAT
Array of stiffness matrices at 7 joints	KS
Bearing stiffness	KTDB
Rigid rotor angular velocity	OM
Case mode natural frequencies	OMC
Rotor mode natural frequency	OMR
Mode shapes	PHI
Alford force cross-coupling curve fit coeff.	QUALF
RPM - rad conversion	RPRD

STABILITY MODEL VARIABLES, con't

Description	Stability Model Variable
Seal damping curvefit coefficients	SC
Seal stiffness curvefit coefficients	SK
Sign(OM)	SOM
Seal cross-coupling curvefit coefficients	SQ
Damping coefficient of case modes	ZEC
Damping coefficient of rotor modes	ZER

APPENDIX F

SSME VARIABLE COMPARISON

Hybrid Simulation	PDP Stability Model
ACB0,ACB1,ACB2	ACB[1-3]
AKB0,AKB1,AKB2	AKB[1-3]
AKTY,AKTZ	KTDB
AKPY(0-4)	AK[1;]
AKPZ(0-4)	AK[2;]
AKTY(0-4)	AK[3;]
AKTZ(0-4)	AK[4;]
BETA	BETA
BKPY,BKPZ	KBUP
BKTY,BKTZ	KBUT
CPY,CPZ	C1
CTY,CTZ	C2
GAM0	GA0
GAM1	GA1
I1	I1
I2	I2
PHICPY,PHICPZ	(M**-.5)PHI[1;2,3;8-17]
PHICTY,PHICTZ	(M**-.5)PHI[2;2,3;8-17]
PHICBX	(M**-.5)PHI[3;1;8-17]
PHICBY,PHIBPZ	(M**-.5)PHI[3;2,3;8-17]
PHICAY,PHICAZ	(I2**-.5)PHI[4;2,3;8-17]
PHICS1Y,PHICS1Z	(I2**-.5)PHI[5;2,3;8-17]

SSME VARIABLE COMPARISON, con't

Hybrid Simulation	PDP Stability Model
PHICS2Y,PHICS2Z	(M**-.5)PHI[6;2,3;8-17]
PHICS3Y,PHICS3Z	(M**-.5)PHI[7;2,3;8-17]
PHIRPY,PHIRPZ	(M**-.5)PHI[1;2,1-7]
PHIRTY,PHIRTZ	(M**-.5)PHI[2;2,3;1-7]
PHIRBX	(M**-.5)PHI[3;1;1-7]
PHIRBY,PHIRBZ	(M**-.5)PHI[3;2,3;1-7]
PHIRAY,PHIRAZ	(I2**-.5)PHI[4;2,3;1-7]
PHIS1Y,PHIS1Z	(I2**-.5)PHI[5;2,3;1-7]
PHIS2Y,PHIS2Z	(M**-.5)PHI[6;2,3;1-7]
PHIS3Y,PHIS3Z	(M**-.5)PHI[7;2,3;1-7]
PHIDXA	AOM
QA(0-4)	24*QALF(1-5)
SCA(0-2)	SC[;4]
SC1(0-2)	SC[;1]
SC2(0-2)	SC[;2]
SC3(0-2)	SC[;3]
SKA(0-2)	SK[;4]
SK1(0-2)	SK[;1]
SK2(0-2)	SK[;2]
SK3(0-2)	SK[;3]
SQA(0-2)	SQ[;4]
SQ1(0-2)	SQ[;1]
SQ2(0-2)	SQ[;2]
SQ3(0-2)	SQ[;3]
TWOZETC	2*ZEC
TWOZETR	2*ZER